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This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

CHARLES BATES, JR.
Chief
Human Engineering Division
Aerospace Medical Research Laboratory

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The procedures for using the SAINT simulation program to analyze systems models are described in detail. SAINT (Systems Analysis of Integrated Networks of Tasks) is a network modeling and simulation technique developed to assist in the design and analysis of complex man-machine systems. SAINT consists of a symbol set for modeling systems and a computer program for analyzing such models. SAINT provides the conceptual framework

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for representing systems that consist of discrete task elements, continuous state variables, and interactions between them. While SAINT was designed for modeling manned systems in which human performance is a major concern, it is potentially applicable to a broad class of systems--those in which discrete and continuous elements are to be portrayed and quantified and whose behavior exhibits time-varying properties. SAINT provides a mechanism for describing these dynamics so a systematic assessment can be made of the relative contribution system components make to overall system performance. In this report, the methodology required to perform a statistical analysis of SAINT output using the SPSS statistical package is illustrated. A remotely piloted vehicle/ drone control facility (RPV/DCF) system in which five RPVs fly along a flight path to a target under the control of a single operator DCF is hypothesized. A SAINT model of this system is developed and documented. Execution of the SAINT model causes the preparation of a file of data that can be directly input to the SPSS statistical routines. With this data, the SPSS package is used to perform statistical analyses relating to the operation of the hypothesized RPV/DCF system.

SUMMARY

This report describes the use of an external statistical analysis package to analyze SAINT output. SAINT (Systems Analysis of Integrated Networks of Tasks) is a package of computer routines designed to aid the system designer and human engineer in analyzing complex man-machine systems. It provides the conceptual framework which allows the development of system models in which men, machines, and the environment are represented. It permits the assessment of the effect of the component characteristics of the system on overall system performance. The symbolism and terminology required for modeling systems using SAINT are introduced and described in Simulation Using SAINT: A User-Oriented Instruction Manual (1). The procedures for using the SAINT simulation program to analyze system models is described in The SAINT User's Manual (2). The overall structure and individual FORTRAN subprograms of SAINT are described in Documentation for the SAINT Simulation Program (3).

In this report, the methodology required to perform a statistical analysis of SAINT output using the SPSS statistical package is illustrated. A remotely piloted vehicle/drone control facility (RPV/DCF) system in which five RPVs fly along a flight path to a target under the control of a single operator DCF is hypothesized. A SAINT model of this system is developed and documented. Execution of the SAINT model causes the preparation of a file of data that can be directly input to the SPSS statistical routines. With these data, the SPSS package is used to perform statistical analyses relating to the operation of the hypothesized RPV/DCF system.

The RPV/DCF system hypothesized and the analyses performed in this report are designed solely for illustrative purposes. The RPV/DCF system does not represent any existing or planned real-world system. The analyses are not intended to be comprehensive. However, the techniques described here can be used to set up statistical analyses for outputs from any SAINT model.

PREFACE

This study was initiated by the Human Engineering Division, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio 45433. The research was conducted by Pritsker & Associates, Inc., P.O. Box 2413, West Lafayette, Indiana 47906. The work was performed in support of Project 7184 "Man-Machine Integration Technology," task 718413 "Man-Machine Models for System Performance Assessment." The research sponsored by this contract was performed between August, 1975 and December, 1976, under Air Force contract F33615-76-C-5012.

In developing this example and the SAINT technique, the authors received guidance and assistance from many individuals, especially the staff members of Pritsker & Associates and the Aerospace Medical Research Laboratory. We appreciate their efforts and acknowledge their contributions.

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SECTION I

INTRODUCTION

Simulation programs produce output data that frequently require additional statistical analysis. The SAINT program is an example. Since packages of statistical routines are available, it appears desirable to provide an interface between SAINT output data arrays and these analysis packages.

The mechanism to achieve this interface has been designed into SAINT through subroutine ENDIT. With this subroutine, the user can communicate SAINT data structures to any set of analysis routines without modifying or recoding the existing routines of the statistical package. In this manual, the statistical computer package SPSS, Statistical Package for the Social Sciences, is used in conjunction with a SAINT model to illustrate the interface.

SPSS[1] is an integrated system of computer programs for use in the analysis of scientific data. The system provides a comprehensive package that enables the user to perform various types of data analysis. Among the statistical capabilities provided by SPSS are:

1. data transformation
2. file manipulation
3. descriptive statistics
4. simple frequency distributions
5. cross tabulations
6. simple correlation
7. partial correlation
8. means and variances for stratified subpopulations
9. one-way and n-way analysis of variance

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[1]All information concerning SPSS used in this example is described fully in reference material (4).

10. multiple regression

11. discriminant analysis

12. scatter diagrams

13. factor analysis

14. canonical correlations

15. Guttman scaling

The SPSS capabilities employed for the analysis of the example SAINT model are directly related to the objectives of the modeling effort. These objectives and the SPSS procedures will be defined in later paragraphs.

To illustrate the SAINT-SPSS interface, a SAINT model of a hypothetical mock-up of a drone control facility (DCF) in which one operator monitors and controls the flight of five remotely piloted vehicles (RPVs) is employed. The RPV/DCF system modeled is a simplification of the real-world RPV/DCF system that has been postulated by the Aerospace Medical Research Laboratory (AMRL) of the United States Air Force.[2] This simplified model is used so that the SAINT-SPSS interface can be clearly presented and described free from any possible confusion that is attendant to a discussion of a complex model. However, the procedures for providing the interface are applicable to any model independent of size and complexity.

The purpose of this study is to demonstrate the total SAINT simulation process, including a description of the system to be modeled, the development of the SAINT model, the coding of the input data, and the SPSS analysis performed on the outputs. This translates into the following objectives:

1. To provide an example illustrating both the application of SAINT modeling concepts and preparation of the input data.

2. To exercise the SAINT model and produce outputs of performance and design measures in a form that is acceptable as SPSS input.

3. To analyze these outputted variables using SPSS to determine relationships between system design and system performance.

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[2]The postulated real-world system is described in detail in reference material (5,6,7), as is the SAINT model of the RPV/DCF real-time simulation of the postulated system (8,9).

SECTION II

RPV/DCF SYSTEM

Figure 1 is a pictorial description of the RPV/DCF system. As the RPVs fly from launch to target, two communication links will exist between the operator at the DCF and each RPV. The position reporting data link (PR) reports the position of the RPV to the DCF operator. The command data link (CL) transmits commands from the DCF operator to the RPV. PR and CL information is passed between the RPV and DCF through a relay aircraft to overcome terrain interference. These links transmit messages every five seconds without any communications error.

All five RPVs of the mission are "strike" RPVs that will deliver their payload at the time that they achieve the target. The first RPV will be launched at time five seconds and the others at five second intervals from this time.

The RPVs will perform the mission without suffering any adverse effects from faulty equipment or enemy defenses, and it is assumed that sufficient fuel is available to complete their flight.

RPV Flight

The RPVs fly from launch to target along a flight path. The flight path flown by all RPVs is depicted in Figure 2 and defined in Table 1. Upon achieving the target, T, the RPV will automatically deliver its payload and return to the launch site for recovery without any direction from the DCF. The flight of the RPVs along their flight paths or along a directional patch (heading change) requested by the operator is linear from point to point on the flight path or patch.

In flight, the RPVs are to maintain an altitude of 200 feet and a velocity of 400 knots. The navigation systems on-board the RPVs will maintain the altitude of 200 feet without error; however, they will not maintain the command velocities of 400 knots, and the true velocity will vary around this value.

In addition to velocity or "ground speed" errors, the navigation system will produce directional or "ground course" errors. Thus, the RPVs will deviate from their flight paths and require external monitoring by the DCF.

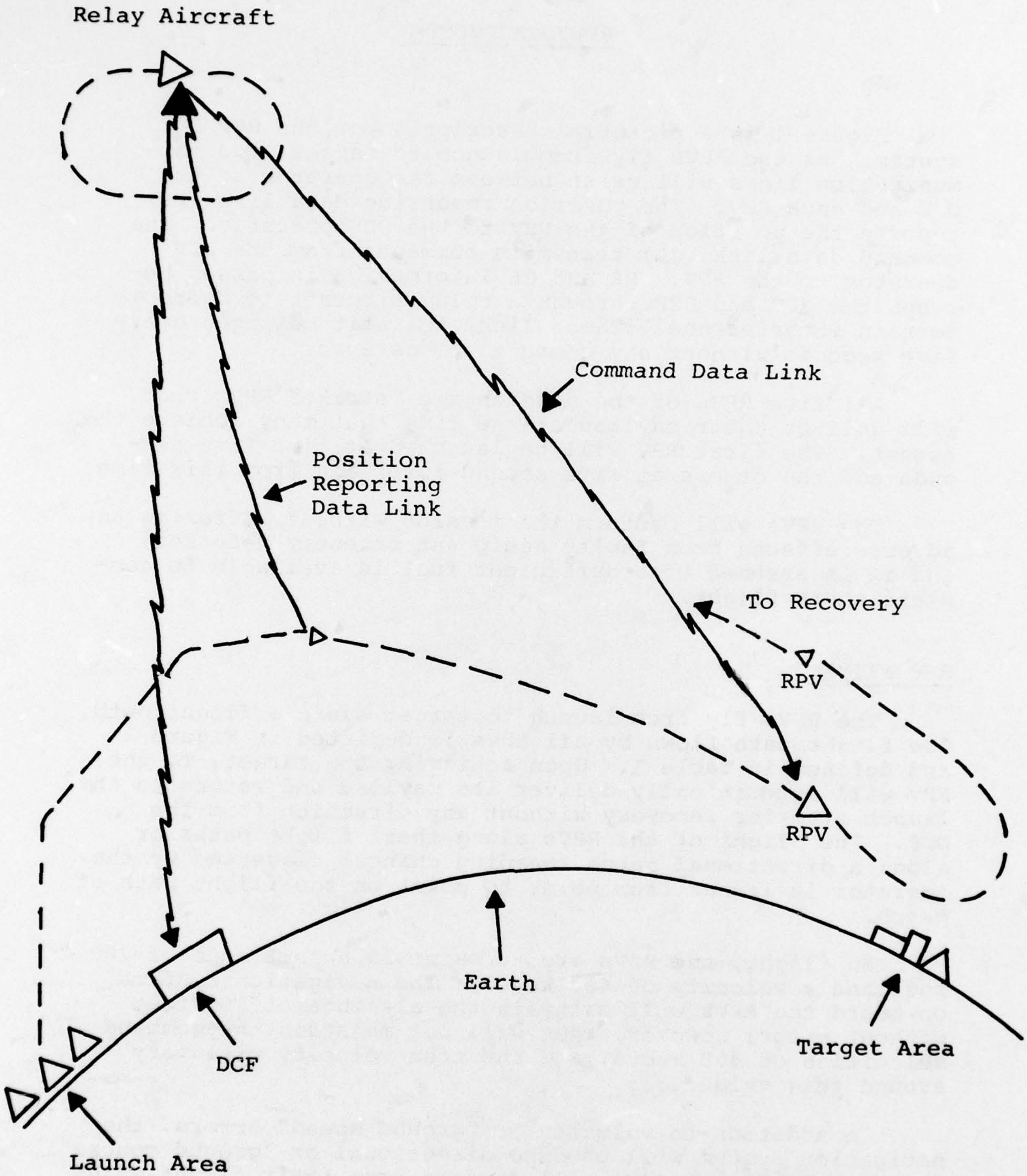

Figure 1. Pictorial Description of RPV/DCF System.

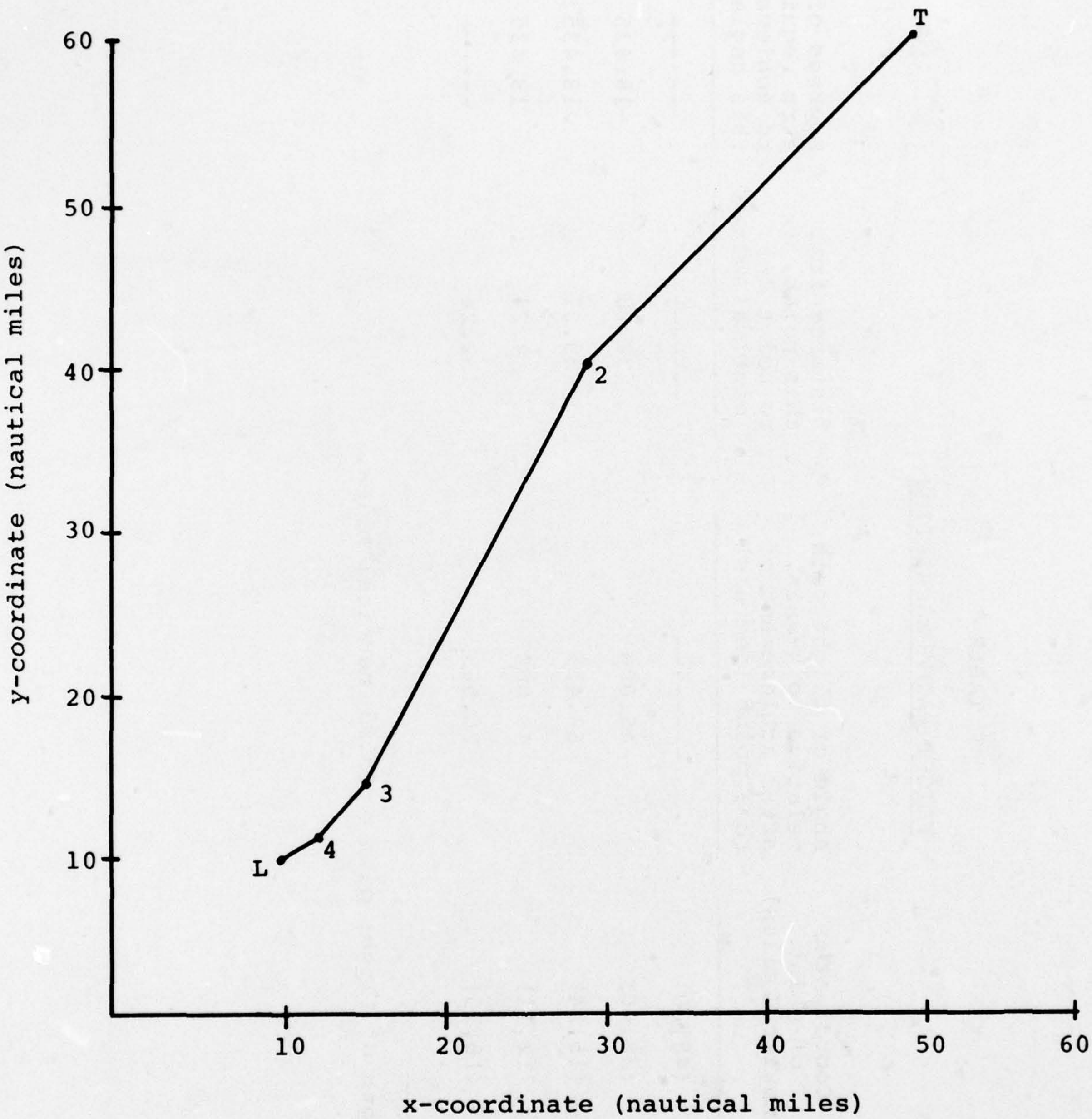

Figure 2. Flight Path of RPVs.

TABLE 1

FLIGHT PATH DESCRIPTION

Flight Path Point	Coordinates of point (nautical miles)	Angle of flight path, relative to x-axis, after achievement of this point (degrees)	Distance from this point, J, to point J-1 (nautical miles)*	Degrees of turn required to achieve this angle
T	(48,60)	--------	---------	-------
2	(28,40)	45.000	28.28	-18.435
3	(15,14)	63.435	29.07	18.435
4	(12,11)	45.000	4.24	18.435
L	(10,10)	26.565	2.24	------

*Total length of flight path = 63.83 nautical miles.

To report RPV flight deviation to the DVF, flight path position variables are defined. The position where the RPV would be if it was on the original flight path is defined as the VFPPE position. The actual position of the RPV is defined as the TRUE position. The deviation of the RPV from the flight path is then computed by constructing a line perpendicular to the flight path through the TRUE position. Call XX the point of intersection of this line with the flight path. The "cross track error" or "lateral direction" of the RPV is then the distance between XX and the TRUE position. The "ground speed error" of the RPV is the distance between XX and the VFPPE position.

In addition to the TRUE and VFPPE position of the RPV, the FPPE position of an RPV is defined. Since the DVF operators can make adjustments to the flight of RPVs, the RPVs will navigate according to these adjustments and not according to the original flight path. The FPPE is thus defined as the position where the RPV would be if it was on the revised flight path. (The RPV will deviate from these adjustments depending on the accuracy of the navigation systems.) Once the RPV has navigated the adjustment to the flight path or "patch" specified by the DCF operator, the FPPE and VFPPE positions are identical.

DCF Operation

The DCF operator will monitor the status of the mission through the use of a visual CRT display of RPV flight. The CRT display is depicted in Figure 3. It consists of a request block and two information blocks which can present RPV status every five seconds. In the status block, the operator receives the current value of the lateral deviation of an RPV from its flight path. The patch block presents a 10nm x 10nm view of the true and desired (VFPPE) flight path positions of an RPV centered around the VFPPE. The operator uses this block to request a directional change (patch) to an RPV. The request block is used by the operator to control the two information displays.

The request block consists of two squares, labeled "STATUS" and "PATCH", and five circles labeled by RPV number that are all recognized by the CRT console when indicated by a light pen of the DCF operator. To request the status of an RPV, the operator light pens "STATUS" and light pens the number of the RPV for which he requests the status. To patch an RPV, the operator light pens "PATCH", light pens the RPV, waits for the patch display to be presented, and light pens the flight path of the RPV shown in the patch

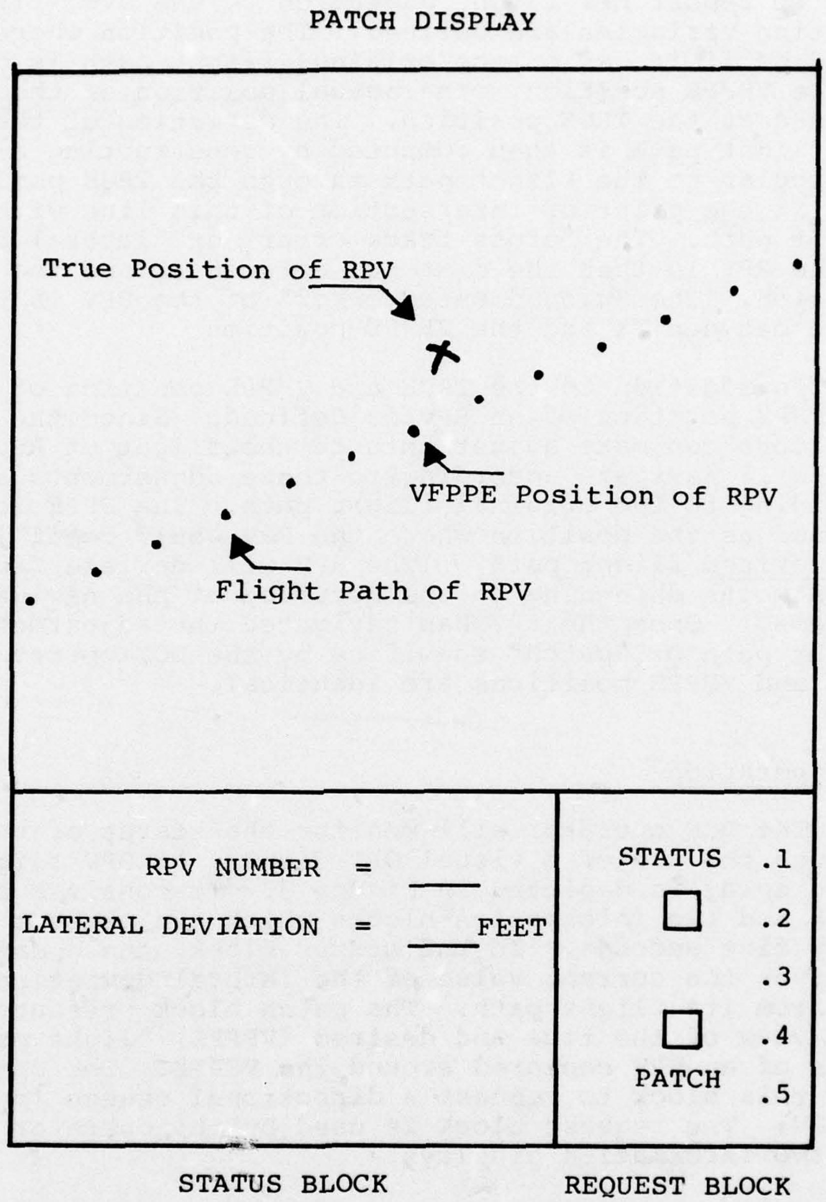

Figure 3. CRT Display.

display three dots ahead of the VFPPE of the RPV (dots are spaced at one nautical mile intervals). (For an RPV not currently in flight, the circle for this RPV is not presented to the operator.)

The operator is required to keep the RPVs on course until they reach the target, and he accomplishes this by patching an RPV via the CRT console when he determines that the RPV is too far off course. The procedures that the operator is required to use in performing a mission are:

1. Continuously consider the RPVs that are in flight in numerical succession beginning with RPV 1.

2. For the RPV being considered, obtain the status display.

3. From this display, determine if the lateral deviation of the RPV is greater than the control criterion, x (the lateral deviation of the RPV above which the operator is required to patch).

4. If it is, request the patch display for this RPV; otherwise consider the next RPV.

5. Determine if there is a turn on the screen within the next five miles (the patch display will not appear if this is the case, it will print "TURN PENDING ON FLIGHT PATH").

6. If there is, consider the next RPV, otherwise, patch the RPV.

The operator of the DCF performs the above procedure as designed, except for one case. Occasionally (Y percent of the time), he does not request the patch display (Step 4) when the lateral deviation in the status block is in fact greater than X.

Since the operator is not concerned with the times of arrival of the RPVs at the target, he is not required to make any velocity changes. The patches made by the operator require only one point as the computer calculates the turn and rolls out required by the RPV to achieve the requested point (or reconnect).

Command Processing

Whenever the operator inputs a patch command, the command is delayed until the second five second interval following its input. When this time occurs, the command is processed and sent to the RPVs.

SECTION III

OBJECTIVES

As indicated previously, the purpose of this study is to demonstrate how SPSS routines can be used to process the output of a SAINT simulation to facilitate the analysis of results. The SAINT model will output performance and design measures in a form acceptable as SPSS input. SPSS will then be used to analyze these outputted variables and to determine relationships between system design and system performance.

The system will be evaluated based on the average linear distance between the RPV and the target at the time the RPVs deliver their payload. In addition, the following performance measures will be considered in the analysis.

1. Average cross track error of the RPVs during their travel to the target, sampled every five seconds for those RPVs in flight.

2. Average ground speed error of the RPVs during their travel to the target, sampled every five seconds for those RPVs in flight.

As implied in the discussion of the model, the following variables will be treated as experimental design variables and used for the analysis:

1. Navigation System Type.

2. X, the control criterion which determines when the operator is required to patch.

3. Y, the probability that the operator will patch an RPV when he notices that the lateral deviation of an RPV is greater than X.

The analysis to be performed using the model attempts to determine the following:

1. If the operator can follow the operational procedures:

    a. What navigation system type should be supplied to the RPVs?

b. What control criterion should the operator employ in patching RPVs (the value of X)?

2. For the model specified above:

   a. Does operator conscientiousness (as described by Y) affect mission performance?

   b. Do the two performance measures outlined above predict mission performance?

SECTION IV

METHODOLOGY

The first stage of the analysis will examine the choice of navigation systems. Two navigation systems are available for RPVs. Navigation System A, a dead reckoning basic system, produces a speed error on the RPVs that is normally distributed with a mean of 0 knots and a standard deviation of 10 knots. The ground course error resulting from this type of navigation system is also normally distributed with mean of 0 and a standard deviation of .035 radians. Navigation System B, an inertial system, causes speed errors that are normally distributed with a mean of 0 and a standard deviation of 2 knots; it produces normally distributed ground course errors with a mean of 0 and a standard deviation of 0.005 radians.

From an economic point of view, a dead reckoning basic system is preferred to an inertial system. Thus, unless there is a statistically significant difference in the performance due to these two systems, the basic system will be selected. To test for this significance, an Analysis of Variance (ANOVA[3]) is to be performed. ANOVA is used to test for statistically significant differences between design variables ("treatments"). In this case a completely randomized design with four replications per cell will be used to test for navigation system differences at the two fixed navigation system levels, A and B, and at control criterion levels (X) of 0 and 1000 feet. The ANOVA analysis will indicate:

1. If there are significant differences, in terms of system performance, between navigation systems.

2. If there are significant differences, in terms of system performance, between the selected levels of the control criterion.

3. If there are significant interaction effects between the navigation systems and the control criterion.

This analysis will be performed using the SPSS ANOVA package. The significance level for the test is set at 0.05, i.e., $\alpha = 0.05$.

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[3]ANOVA is discussed fully in reference material (10,11,12).

The results of the ANOVA analysis will be considered qualitatively and the "best" navigation system will be chosen. In making a selection, intangible elements need to be considered. Bear in mind, this is solely an example of the use of the SPSS-SAINT interface.

After the navigation system is selected, a detailed consideration of the control criteria will be made. The attempt will be to select the most effective criterion level, in terms of mission performance and operator workload, for use with the selected navigation system. Five control criterion levels (X) are to be considered: 0, 250, 500, 750, and 1000 feet. The SPSS SCATTERGRAM routines will be used to plot the performance versus control criterion (four replications of the mission at each level of the control criterion will be performed.

From the scattergram, the "best" level for the control criterion will be selected. At this point the RPV/DCF operating system will be established and further analysis will apply only to this system definition.

The next stage of analysis will attempt to discern how operator performance, as measured by Y, influences system performance. Four replications will be run at four values of Y. The values selected are Y = 1.0, 0.8, 0.6, and 0.4. The SPSS REGRESSION package will be used to assess a hypothesized linear relationship between mission performance and Y. This analysis will help provide recommendations for operator training and selection.

The last analysis to be performed on this system will be to determine the relationship between the performance measure used (average linear distance from target) and the two performance variables collected that were not used as a measure of mission success (average cross track and ground speed errors). The SPSS PEARSON CORR program will be employed here. This analysis will provide information on how well these other performance variables can predict overall mission success and could aid in identifying appropriate operating training techniques. The sixteen replications performed above will be used for this analysis.

The above procedures will clearly illustrate how SAINT and SPSS can be coordinated to analyze simulation results and provide some insights into RPV/DCF system design.

SECTION V

SAINT MODEL OF THE RPV/DCF SYSTEM

The SAINT model of the RPV/DCF system is depicted in Figure 4. The following sections will present the technical documentation for this model. Each task in the SAINT network is described in detail. Then the definitions of the information attributes, resource attributes, user functions, moderator functions, distribution sets, and user statistics used in the model are presented. The state variables and monitors used in the model are then described. Lastly, the definition of the user-common variables are presented with a listing of each user-written subprogram.

The data input and SAINT output for this model are given in Appendices A, B, and C. Appendix A lists the SAINT and user-supplied input to the model. Appendix B presents the SAINT echo check of the data. Appendix C provides examples of the statistics and histograms generated for each simulation of the model.

Tasks of the SAINT Network

This section describes the tasks of the SAINT network which is presented in Figure 4. Each task will be fully defined in terms of conditions causing its release, represented activity, purpose, performance time, attribute assignment information, and branching characteristics. Before each task is discussed individually, some characteristics common to all tasks will be presented.

1. All tasks have a priority of 0.0 unless otherwise specified.

2. No special SAINT statistics are kept for any task.

3. Assignments (at all tasks that have assignments) are made at the completion of the task unless otherwise specified.

Tables 2, 3, 4, 5, 6, and 7 at the end of this section summarize the information attributes, resource attributes, user functions, moderator functions, distribution sets, and statistical codes used in the model, respectively.

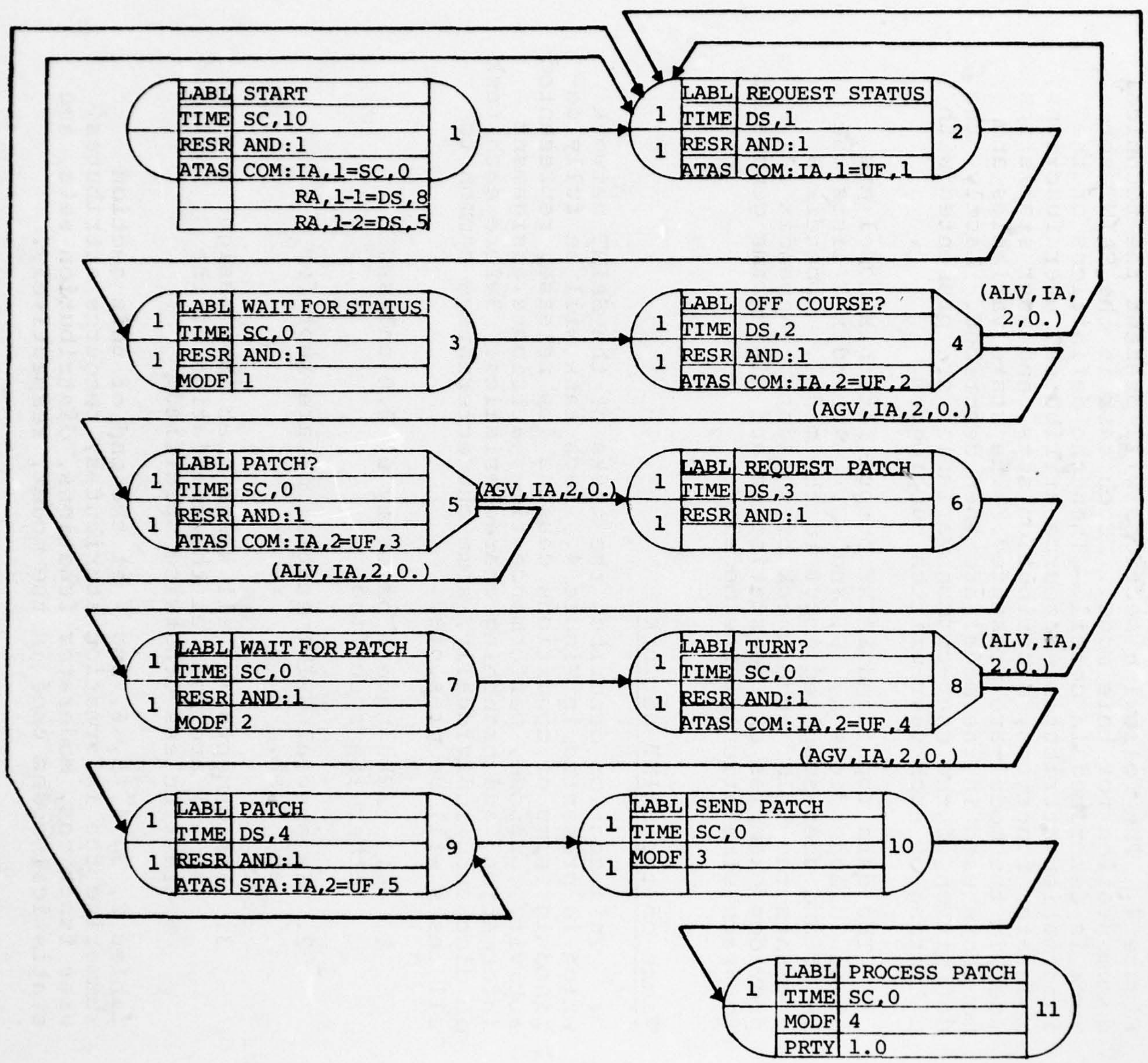

Figure 4(1). SAINT Network Model of the RPV/DCF System.

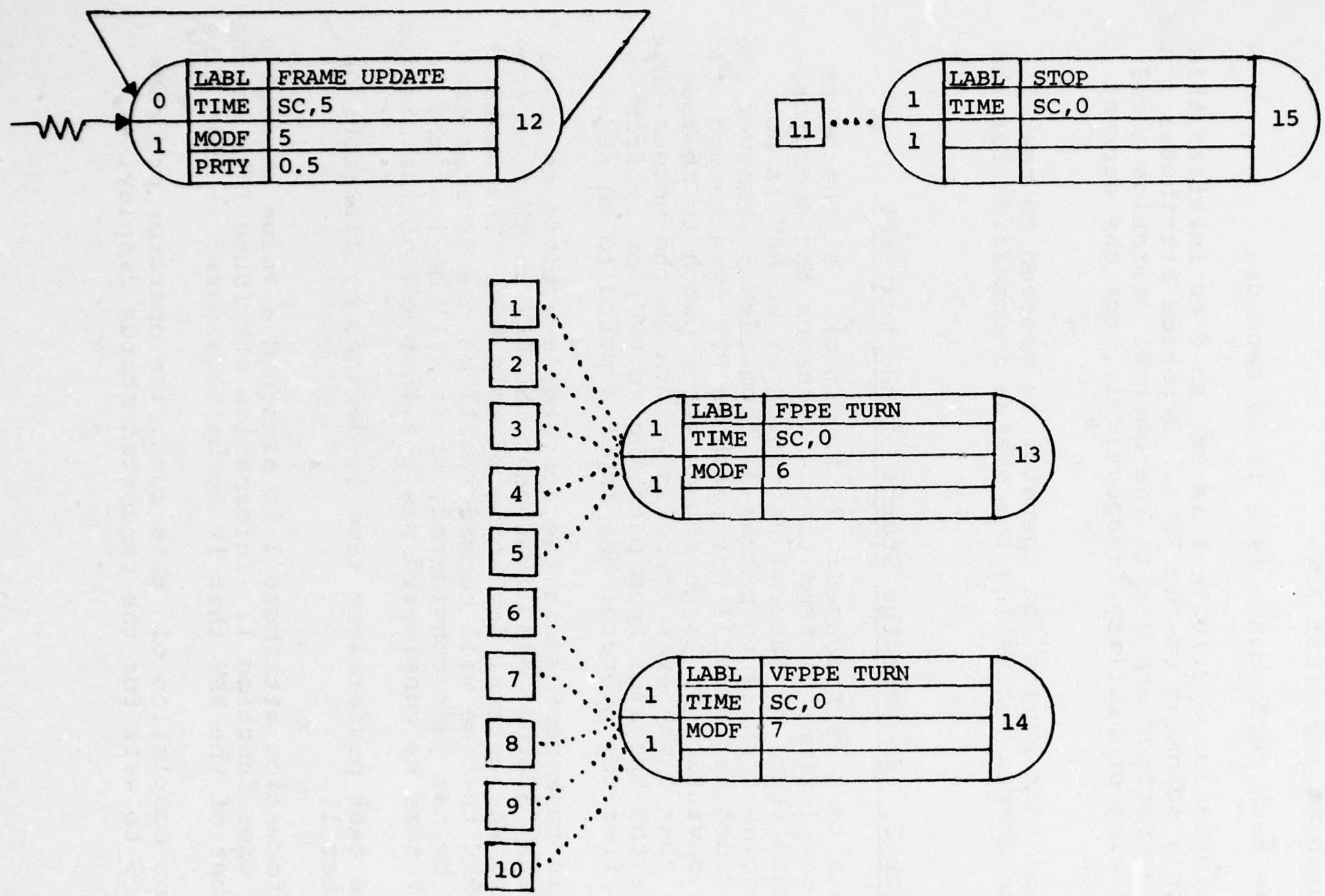

Figure 4(2). SAINT Network Model of the RPV/DCF System.

Task 1. Await the Launch of the First RPV

This task is released at the start of the simulation and initiates the activities of the operator, resource 1, the only resource involved in the simulation.

This activity represents the operator's waiting for the launch of the first RPV.

The task performance time is 10 seconds.

Information attribute 1 is set to 0 to initiate this operator's scanning of the RPVs. Resource attributes 1 and 2 of the operator are set to the control criterion level and patching probability, respectively, for the current iteration.

This task causes the operator to proceed to task 2 where he starts requesting the status information for the RPVs.

Task 2. Request the Status of the Next RPV

This task is released: 1) from task 1 at the start of the simulation; 2) from task 4 whenever the operator determines that the lateral deviation of an RPV is not large enough for him to patch; 3) from task 5 whenever the operator decides he will not patch an RPV even though its lateral deviation is large enough for a patch to be made; 4) from task 8 whenever there is a turn on the screen that prevents the operator from patching an RPV; or 5) from task 9 after the operator has input a patch to an RPV.

This task represents the operator's activities as he light pens "STATUS" and light pens the RPV so that he can determine the lateral deviation of this RPV. The number of the RPV that he will consider will be one greater than the RPV he has just considered, or it will be 1 if the last RPV that he considered was the last RPV of the mission.

The task performance time is defined by distribution set number 1.

Information attribute 1 is assigned a value through a call to user function 1. Information attribute 1 is set to the number of the RPV that is to be considered at this time.

Upon completion of this task, the operator proceeds to task 3 to wait for the requested status display.

Task 3. Wait for Status Display

This task is released whenever the operator has requested a status display for an RPV at task 2.

This task represents the operator's activities as he waits until the status display is presented.

The task performance time is computed in moderator function 1 as the time to the next 5 second interval.

No attribute assignments are made at this task.

This task causes the operator to proceed to task 4, where he decides whether or not to patch this RPV based on the status information.

Task 4. Determine If a Patch Is Required

This task is released from task 3 whenever the status display for an RPV has been requested and received by the operator.

This task represents the operator's activities as he decides whether or not the lateral deviation of the RPV is large enough to cause him to patch. The operator will determine that the lateral deviation value is large enough to cause him to patch whenever it is greater than the value of his resource attribute 1, defined as that value above which he is required to patch an RPV.

The task performance time is defined by distribution set number 2.

Information attribute 2 is assigned the value in user function 2 to reflect the operator's decision at this task. Information attribute 2 is set to 1 if the lateral deviation value of his RPV is large enough to cause this operator to patch. It is set to 0 otherwise.

The operator proceeds from this task based on his decision as defined in information attribute 2. If he is required to patch this RPV, he will proceed to task 5 which determines whether or not he actually will patch the RPV. Otherwise, he will return to task 2 to consider status checks on other RPVs.

Task 5. Determine If the Operator Will Patch

This task is released from task 4 whenever the operator discovers that he is required to patch an RPV at this time.

This task represents the operator's activities as he determines whether or not he will patch the RPV. The operator occasionally will not patch an RPV when it is required. He will only patch an RPV at this point Y% of the time, where Y is defined in resource attribute 2.

The task performance time is 0.

Information attribute 2 is assigned a value in user function 3 that reflects the operator's patching operations. If he will patch the RPV, information attribute 2 is set to 1. Otherwise, information attribute 2 is set to 0.

The operator proceeds from this task based on the decision process as defined above. If he will patch the RPV, he proceeds to task 6 to start the patch operation. Otherwise, he returns to task 2 to consider status checks on other RPVs.

Task 6. Request the Patch Display

This task is released whenever the operator, at task 5, decides to perform a patch on an RPV.

This task represents the operator's activities as he light pens "PATCH" and light pens the RPV. By performing these functions, the operator is requesting the patch display so he can patch the RPV.

The task performance time is defined in distribution set 3.

No attribute assignments are made at this task.

The operator proceeds from this task to task 7, where he waits for the patch display to be presented.

Task 7. Wait for the Patch Display

This task is released from task 6 whenever the operator has requested a patch display.

This task represents the operator's activities as he waits for the display to be presented.

The task performance time is computed in moderator function 2, which computes the time to the next five second interval after the release of this task.

No attribute assignments are made at this task.

After waiting for and receiving the patch display, the operator proceeds to task 8 where he determines whether or not there is a turn on the console screen that will prevent him from patching this RPV.

Task 8. Determine If a Turn Prevents Patching

This task is released from task 7 after the operator has requested and received the patch display.

This task represents the operator's activities as he determines whether or not there is a turn on the console screen that will prevent him from patching this RPV. A patch will be prevented whenever the next flight path turn of the RPV is less than five nautical miles from the RPVs current VFPPE. The operator is automatically informed of this condition. Consequently, the task performance time is 0.

Information attribute 2 is assigned a value in user function 4 that reflects the turn conditions of this RPV. If there is a turn on the screen that prevents the operator from patching this RPV, information attribute 2 is set to 0. If not, information attribute 2 is set to 1.

The operator proceeds from this task based on the turn conditions discussed above. If a turn prevents him from patching this RPV, he returns to task 2 to consider status checks on other RPVs. If no turn prevents his patching, he proceeds to task 9 to input the patch for this RPV.

Task 9. Input the Patch Points

This task is released from task 8 whenever the operator has determined that a patch is to be made on an RPV. He arrives at this node with the console screen prepared to accept patch points.

This task represents the operator's activities as he inputs the patch point through the console screen. The operator will input one patch point along the flight path of the RPV. The point is set 3.0 nautical miles ahead of the VFPPE position of the RPV.

The task performance time is defined by distribution set 4.

User function 5 is called at the start of this task, to assign values to information attributes 3 and 4. These information attributes will be assigned values that represent the x-position of the patch point and the y-position

of the patch point, respectively.

After inputting the patch point, the operator proceeds to task 2 where he continues to consider status checks on other RPVs. The command input by the operator, as represented by the information attribute packet, proceeds to task 10 for processing.

Task 10. Delay the Patch Command Before Transmission

This task is released from task 10 after the operator inputs a patch for an RPV.

The purpose of this task is to represent a processing delay between the command input and the command transmission.

No resources are required for the performance of this task.

The task performance time is computed in moderator function 3, which computes the time to the second frame update following the release of this task. This time represents the delay indicated above.

No attribute assignments are made at this task.

The information attribute packet representing the patch command proceeds to task 11 for processing.

Task 11. Process the Patch Command

This task is released from task 10 whenever a command is to be processed.

The purpose of this task is to process the patch command input by the operator. The commands input by the operator are processed at this task through a call to moderator function 4, which updates all the pertinent state variables to reflect the command. This updating includes the definition of a revised flight path segment for the RPV between its current position and the patch point requested. The RPV will follow this revised flight path from the time the patch takes effect until the RPV reaches the patch point.

No resources are required for the performance of this task.

The task performance time is 0.

No attribute assignments are performed at this task.

No branching occurs from this task.

The task priority is set to 1.0 to insure that command processing is performed before information is updated at task 12.

Task 12. Process the Frame Update

This task is released at the beginning of the simulation and every five seconds thereafter.

This task processes the frame update information. This information is processed through a call to moderator function 5, which updates all the pertinent program variables.

No resources are required for the performance of this task.

The task performance time is 5 seconds.

No attribute assignments are made at this task.

This task branches back to itself for the processing of the next frame update.

The task priority is set to 0.5 to insure that the update is processed before the operator accesses it and to insure that existing command processing is reflected in the updated information.

Task 13. Process an FPPE Turn

This task is signaled through a monitor whenever it is time for an RPV to alter its course according to its revised flight path. (If no revised flight path segments are currently in effect, the revised flight path is the same as the original flight path.)

The purpose of this task is to cause the FPPE and the true position of the RPV to turn towards the next flight path point. This is accomplished through a call to moderator function 6, which updates all the pertinent program variables.

No resources are required for the performance of this task.

The task performance time is 0.

No attribute assignments are made at this task.

No branching occurs from this task.

Task 14. Process a VFPPE Turn

This task is signaled through a monitor whenever it is time for an RPV to alter its course according to its original flight path.

The purpose of this task is to cause the VFPPE position of an RPV to change its heading and move towards the next flight path point. This is accomplished through a call to moderator function 7, which updates all the pertinent program variables. The RPV is not turned at this task as it may be following a revised flight path segment. However, if a revised flight path segment is not in effect, task 13 will be processed at the same time as this task.

No resources are required for the performance of this task.

The task performance time is 0.

No attribute assignments are made at this task.

No branching occurs from this task.

Task 15. End the Simulation

This task is signaled through a monitor whenever all the RPVs have achieved their targets.

The purpose of this task is to cause the end of the simulation.

No resources are required for the performance of this task.

The task performance time is 0.

No attribute assignments are made at this task.

This task is a sink task and branches to end the simulation.

State Variables and Monitors

State variables for the SAINT model of the RPV/DCF system represent flight parameters. SS(1)-SS(5) represent the time of the next turn for the FPPE of RPVs 1-5, respectively. SS(6)-SS(10) are set to the time of the next VFPPE turn for RPVs 1-5. SS(11)-SS(15), SS(16-SS(20), SS(21)-SS(25), SS(26)-SS(30), SS(31)-SS(35), and SS(36)-SS(40) are, respectively, the true x-coordinates, the true y-coordinates, the FPPE x-coordinates, the FPPE y-coordinates, the VFPPE x-coordinates, and the VFPPE y-coordinates of the RPVs. SS(41) represents the current time and SS(42) is a flag used for halting the simulation when all RPVs have achieved the target. These state variables are defined more fully in Table 8.

Monitors 1-5 detect the next turn for the FPPEs of RPVs 1-5, respectively. Monitors 6-10 detect the turns for the VFPPEs of RPVs 1-5, respectively. Monitor 11 detects SS(42) crossing 1.0 to end the simulation. The monitors are presented in Table 9.

TABLE 2

INFORMATION ATTRIBUTE DEFINITIONS

Information Attribute	Definition
1	Number of RPV being considered.
2	Decision Value: See Table 4 for definition at each task.
3	X-coordinate of patch point of an operator's patch.
4	Y-coordinate of patch point of an operator's patch.

TABLE 3

RESOURCE ATTRIBUTE DEFINITIONS

Resource Attribute	Definition
1	Lateral deviation value of an RPV above which operator is required to patch the RPV (control criterion).
2	Probability that operator will patch an RPV when he notices that its lateral deviation is greater than resource attribute 1.

TABLE 4

DESCRIPTION OF USER FUNCTIONS

User Function	Function of User Function	Task Calling This User Function
1	Determine number of next RPV to be considered for a status check. Set information attribute 2 to the number of this RPV.	2
2	Determine if the lateral deviation of this RPV is high enough to cause the operator patch. Set information attribute 2 to 1 if it is; to 0 otherwise.	4
3	Determine if the operator will patch this RPV. Set information attribute 2 to 1 if he will; to 0 otherwise.	5
4	Determine if a turn prevents patching. Set information attribute 2 to 0 if it does, to 1 otherwise.	8
5	Set information attributes 3 and 4, the x- and y-coordinates of the patch point, respectively.	9

TABLE 5

DESCRIPTION OF MODERATOR FUNCTIONS

Moderator Function	Function of Moderator Function	Task Calling This Moderator Function
1	Compute the time until the status information is displayed.	3
2	Compute the time until the console is prepared to accept patch points.	7
3	Compute the time until this patch command is sent to the RPV.	10
4	Process patch command.	11
5	Process frame update.	12
6	Process FPPE turn.	13
7	Process VFPPE turn.	14

TABLE 6

DESCRIPTION OF DISTRIBUTION SETS

Distribuion Set(s)	Parameter Represented	Distribution Type	Mean	Standard Deviation	Minimum	Maximum
1	Seconds it takes operator to press "STATUS" and light pen an RPV	Normal	2	0.5	0	99999
2	Seconds it takes operator to determine if the lateral deviation of an RPV is too high	Normal	2	0.5	0	99999
3	Seconds it takes operator to press "PATCH" and light pen an RPV	Normal	2	0.5	0	99999
4	Seconds it takes operator to input the patch points	Normal	2	0.5	0	99999
5	Probability that operator will patch an RPV when he notices that its lateral deviation is greater than the patching threshold	Constant	0./1.*	-	-	-
6	Mean ground course error for an RPV (radians)	Normal	0	.035/.005**	-99999	99999
7	Mean ground speed error for an RPV (knots)	Normal	0	10/2**	-99999	99999
8	Operator's control criterion (feet)	Constant	0./1000.*	-	-	-

*These values represent the limits of this parameter.
**These values are for the two navigation system types: basic/inertial.

TABLE 7

STATISTICAL CODES

Statistic Type	Statistic Code	Variable Recorded
UCLCT	1	Linear deviation from the target at the time the trigger is pulled for an RPV, observed for each RPV.
UHIST	1	
UCLCT	2	Ground course error for an RPV, observed every five seconds for each RPV in flight to the target.
UHIST	2	
UCLCT	3	Ground speed error for an RPV, observed every five seconds for each RPV in flight to the target.
UHIST	3	

TABLE 8

STATE VARIABLE DEFINITIONS

State Variable Number	Label	Equation in STATE	Initial Value in INTLC
1	FP TRN 1	--	99999.
2	FP TRN 2	--	99999.
3	FP TRN 3	--	99999.
4	FP TRN 4	--	99999.
5	FP TRN 5	--	99999.
6	VP TRN 1	--	99999.
7	VP TRN 2	--	99999.
8	VP TRN 3	--	99999.
9	VP TRN 4	--	99999.
10	VP TRN 5	--	99999.
11	TRUE X 1	SS(11)=SSL(11)+SPEED(1)*TXHED(1)*DTNOW *	10.*CONVF
12	TRUE X 2	SS(12)=SSL(12)+SPEED(2)*TXHED(2)*DTNOW	10.*CONVF
13	TRUE X 3	SS(13)=SSL(13)+SPEED(3)*TXHED(3)*DTNOW	10.*CONVF
14	TRUE X 4	SS(14)=SSL(14)+SPEED(4)*TXHED(4)*DTNOW	10.*CONVF
15	TRUE X 5	SS(15)=SSL(15)+SPEED(5)*TXHED(5)*DTNOW	10.*CONVF
16	TRUE Y 1	SS(16)=SSL(16)+SPEED(1)*TYHED(1)*DTNOW	10.*CONVF
17	TRUE Y 2	SS(17)=SSL(17)+SPEED(2)*TYHED(2)*DTNOW	10.*CONVF
18	TRUE Y 3	SS(18)=SSL(18)+SPEED(3)*TYHED(3)*DTNOW	10.*CONVF
19	TRUE Y 4	SS(19)=SSL(19)+SPEED(4)*TYHED(4)*DTNOW	10.*CONVF
20	TRUE Y 5	SS(20)=SSL(20)+SPEED(5)*TYHED(5)*DTNOW	10.*CONVF
21	FPPE X 1	SS(21)=SSL(21)+CSPED*FXHED(1)*DTNOW	10.*CONVF
22	FPPE X 2	SS(22)=SSL(22)+CSPED*FXHED(2)*DTNOW	10.*CONVF
23	FPPE X 3	SS(23)=SSL(23)+CSPED*FXHED(3)*DTNOW	10.*CONVF
24	FPPE X 4	SS(24)=SSL(24)+CSPED*FXHED(4)*DTNOW	10.*CONVF
25	FPPE X 5	SS(25)=SSL(25)+CSPED*FXHED(5)*DTNOW	10.*CONVF
26	FPPE Y 1	SS(26)=SSL(26)+CSPED*FYHED(1)*DTNOW	10.*CONVF
27	FPPE Y 2	SS(27)=SSL(27)+CSPED*FYHED(2)*DTNOW	10.*CONVF
28	FPPE Y 3	SS(28)=SSL(28)+CSPED*FYHED(3)*DTNOW	10.*CONVF
29	FPPE Y 4	SS(29)=SSL(29)+CSPED*FYHED(4)*DTNOW	10.*CONVF
30	FPPE Y 5	SS(30)=SSL(30)+CSPED*FYHED(5)*DTNOW	10.*CONVF

State Variable Number	Label	Equation in STATE	Initial Value in INTLC
31	VFPP X 1	SS(31)=SSL(31)+CSPED*VXHED(1)*DTNOW	10.*CONVF
32	VFPP X 2	SS(32)=SSL(32)+CSPED*VXHED(2)*DTNOW	10.*CONVF
33	VFPP X 3	SS(33)=SSL(33)+CSPED*VXHED(3)*DTNOW	10.*CONVF
34	VFPP X 4	SS(34)=SSL(34)+CSPED*VXHED(4)*DTNOW	10.*CONVF
35	VFPP X 5	SS(35)=SSL(35)+CSPED*VXHED(5)*DTNOW	10.*CONVF
36	VFPP Y 1	SS(36)=SSL(36)+CSPED*VYHED(1)*DTNOW	10.*CONVF
37	VFPP Y 2	SS(37)=SSL(37)+CSPED*VYHED(2)*DTNOW	10.*CONVF
38	VFPP Y 3	SS(38)=SSL(38)+CSPED*VYHED(3)*DTNOW	10.*CONVF
39	VFPP Y 4	SS(39)=SSL(39)+CSPED*VYHED(4)*DTNOW	10.*CONVF
40	VFPP Y 5	SS(40)=SSL(40)+CSPED*VYHED(5)*DTNOW	10.*CONVF
41	TIME	SS(41)=SSL(41)+DTNOW	0.
42	STOP	--	0.

*Equation variables are defined in Table 10.

TABLE 9

MONITOR INFORMATION

Monitor Number	Monitor Label	Crossing SS Variable	Crossed SS Variable	Additive Constant	Switch Set	New Switch Value	Signaled Task
1	FPPE 1	41	1	0.	1	1	13
2	FPPE 2	41	2	0.	1	2	13
3	FPPE 3	41	3	0.	1	3	13
4	FPPE 4	41	4	0.	1	4	13
5	FPPE 5	41	5	0.	1	5	13
6	VFPPE 1	41	6	0.	2	1	14
7	VFPPE 2	41	7	0.	2	2	14
8	VFPPE 3	41	8	0.	2	3	14
9	VFPPE 4	41	9	0.	2	4	14
10	VFPPE 5	41	10	0.	2	5	14
11	STOP	42	-	1.	-	-	15

User-Written Subprograms

There are five user-written subprograms for the SAINT model of the RPV/DCF system. Subroutine INTLC initializes the user COMMON and state variables of the model and inputs flight path information. Subroutine STATE computes the flight path positions as the simulation progresses. Subroutine MODRF and USERF process the moderator and user functions of the model. Subroutine ENDIT collects the outputs for each iteration and prepares for the next iteration.

Table 10 defines the user COMMON and state variable equivalenced mnemonic variables of the model. Figures 5 through 8 present the FORTRAN listings of subroutines INTLC, STATE, MODRF and USERF. Subroutine ENDIT, which is altered for each phase of the SPSS analysis, will be presented in the next section.

TABLE 10

USER COMMON AND STATE VARIABLE EQUIVALENCED MNEMONIC VARIABLES

Variable Name	Definition	Initial Value	Equivalent SAINT Variable(s)
CONVF	Conversion factor, nautical miles to feet	6080	--
CONVV	Conversion factor, knots to feet per second	6080/3600	--
CSPED	Command speed for the RPVs (feet per second)	400*CONVV	--
CTIME	Simulation time (seconds)	0	SS(41)
ENDSM	Simulation completion index: = 2 if simulation is complete, = 0 otherwise	0	SS(42)
FPPEX(I)	x-coordinate of FPPE of RPV I (feet)	10*CONVF	SS(I+20)
FPPEY(I)	y-coordinate of FPPE of RPV I (feet)	10*CONVF	SS(I+25)
FXHED(I)	x-heading for the FPPE of RPV I	0	--
FYHED(I)	y-heading for the FPPE of RPV I	0	--
IFLY(I)	Flight index for RPV I: = 1 if RPV is flying = 0 otherwise	0	--
NFPPE(I)	FPPE flight path point toward which RPV I is heading	0	--
NVFPP(I)	VFPPE flight path point toward which RPV I is heading	0	--
PI	The value of π (3.141593)	π	--
SPEED(I)	True speed of RPV I	0	--
TFPPE(I)	Time of arrival at the next flight path point on the revised flight path of RPV I (seconds)	99999	SS(I)
TRUEX(I)	True x-coordinate of RPV I (feet)	10*CONVF	SS(I+10)

Variable Name	Definition	Initial Value	Equivalent SAINT Variable(s)
TRUEY(I)	True y-coordinate of RPV I (feet)	10*CONVF	SS(I+15)
TVFPE(I)	Time of arrival at the next flight path point in the original flight path of RPV I (seconds)	99999	SS(I+5)
TXHED(I)	True x-heading of RPV I	0	--
TYHED(I)	True y-heading of RPV I	0	--
VFPPX(I)	x-coordinate of VFPPE of RPV I (feet)	10*CONVF	SS(I+30)
VFPPY(I)	y-coordinate of VFPPE of RPV I (feet)	10*CONVF	SS(I+35)
VXHED(I)	x-heading of VFPPE of RPV I	0	--
VYHED(I)	y-heading of VFPPE of RPV I	0	--
XFPPE(I,J)	x-coordinate of the Jth waypoint on the FPPE flight path of RPV I (feet)	0	--
XLATD(I)	Lateral deviation of RPV I (feet)	0	--
XVFPP(J)	x-coordinate of the Jth waypoint on the VFPPE flight path of all RPVs	0	--
YFPPE(I,J)	y-coordinate of the Jth waypoint on the FPPE flight path of RPV I	0	--
YVFPP(J)	y-coordinate of the Jth waypoint on the VFPPE flight path of all RPVs	0	--

```
      SUBROUTINE INTLC
C
      DIMENSION FPPEX(5),FPPEY(5),TRUEX(5),TRUEY(5),VFPPX(5),VFPPY(5)
      DIMENSION TVFPE(5),TFPPE(5)
      COMMON /UCOM1/ CONVF,CONVV,PI
      COMMON /UCOM2/ CSPED,SPEED(5)
      COMMON /UCOM3/ FXHED(5),FYHED(5),TXHED(5),TYHED(5),VXHED(5),VYHED(
     *5)
      COMMON /UCOM4/ IFLY(5),NFPPE(5),NVFPP(5)
      COMMON /UCOM5/ XFPPE(5,20),YFPPE(5,20)
      COMMON /UCOM6/ XLATD(5),XVFPP(20),YVFPP(20)
      COMMON /COM06/ TNOW,TTNEX,MFAD,SEED,ISEED,NCRDR,NPRNT,NPUNCH,
     *               NRNIT,NRENT,MNOC,NDC,NDTN,NNTC
      COMMON /COM16/ AAERR,DTMAX,DTMIN,DTSAV,IITES,LLERR,RRERR,TTLAS,
     *               TTSAV,DTSUG,DTFUL,DTNOW,ISEES,RESLS,DTACC,LLSAV,
     *               LSAVE
      COMMON /COM17/ SS(100),SSL(100),DD(100),DDL(100),LLSVP(100,2)
      COMMON /COM18/ IS(20),XABAD(300),YABAR(600)
      COMMON /COM22/ TTIME,FFIRB
C
      EQUIVALENCE(SS(41),CTIME),(SS(42),ENDSM)
      EQUIVALENCE(SS(21),FPPEX(1)),(SS(26),FPPEY(1))
      EQUIVALENCE(SS(1),TFPPE(1)),(SS(6),TVFPE(1))
      EQUIVALENCE(SS(11),TRUEX(1)),(SS(16),TRUEY(1))
      EQUIVALENCE(SS(31),VFPPX(1)),(SS(36),VFPPY(1))
C
C
C          INITIALIZE VARIABLES.
C
      CONVF=6080.
      CONVV=6080./3600.
      DO 100 I=1,5
      TFPPE(I)=99999.
      TVFPE(I)=99999.
      TRUEX(I)=10.*CONVF
      TRUEY(I)=10.*CONVF
      FPPEX(I)=10.*CONVF
      FPPEY(I)=10.*CONVF
      VFPPX(I)=10.*CONVF
      VFPPY(I)=10.*CONVF
      XLATD(I)=0.
      SPEED(I)=0.
      FXHED(I)=0.
      FYHED(I)=0.
      TXHED(I)=0.
      TYHED(I)=0.
      VXHED(I)=0.
      VYHED(I)=0.
      IFLY(I)=0
  100 CONTINUE
      PI=3.14159
      CTIME=0.
      CSPED=400.*CONVV
      ENDSM=0.
      DO 200 I=1,5
      DO 150 J=1,20
      XFPPE(I,J)=0.
      YFPPE(I,J)=0.
  150 CONTINUE
      NFPPE(I)=0
```

Figure 5(1). FORTRAN Listing of Subroutine INTLC.

```
      NVFPF(I)=C
  200 CONTINUE
      DO 300 J=1,20
      XVFPP(J)=0.
      YVFPP(J)=0.
  300 CONTINUE
C
C
C          INPUT FLIGHT PATH COORDINATES FOR VFPPE.
C
      READ(NCRDR,10) IPT
      READ(NCRDR,20) (XVFPP(J),J=1,IPT)
      READ(NCRDR,20) (YVFPP(J),J=1,IPT)
      DO 400 J=1,IPT
      XVFPP(J)=XVFPP(J)*CONVF
      YVFPP(J)=YVFPP(J)*CONVF
  400 CONTINUE
C
C          DEFINE FPPE FLIGHT PATH COORDINATES.
C
      DO 500 I=1,5
      NFPPE(I)=IPT
      NVFPP(I)=IPT
      DO 450 J=1,20
      XFPPE(I,J)=XVFPP(J)
      YFPPE(I,J)=YVFPP(J)
  450 CONTINUE
  500 CONTINUE
C
C          SET THE TAKEOFF TIMES OF THE RPVS.
C
      DO 600 I=1,5
      XI=I-1
      TFPPE(I)=5.+5.*XI
      TVFPE(I)=TFPPE(I)
  600 CONTINUE
C
   10 FORMAT(I5)
   20 FORMAT(20F4.0)
C
      RETURN
      END
```

Figure 5(2). FORTRAN Listing of Subroutine INTLC.

```
      SUBROUTINE STATE
C
      DIMENSION FPPEX(5),FPPEY(5),TRUEX(5),TRUEY(5),VFPPX(5),VFPPY(5)
      DIMENSION TVFPE(5),TFPPE(5)
      COMMON /UCOM1/ CONVF,CONVV,PI
      COMMON /UCOM2/ CSPED,SPEED(5)
      COMMON /UCOM3/ FXHED(5),FYHED(5),TXHED(5),TYHED(5),VXHED(5),VYHED(
     *5)
      COMMON /UCOM4/ IFLY(5),NFPPE(5),NVFPP(5)
      COMMON /UCOM5/ XFPPE(5,20),YFPPE(5,20)
      COMMON /UCOM6/ XLATD(5),XVFPP(20),YVFPP(20)
      COMMON /COM06/ TNOW,TTNEX,MFAD,SEED,ISEED,NCRDR,NPRNT,NPUNCH,
     *               NRNIT,NRENT,MNOC,NOC,NOTN,NNTC
      COMMON /COM16/ AAERR,DTMAX,DTMIN,DTSAV,IITES,LLERR,RRERR,TTLAS,
     *               TTSAV,DTSUG,DTFUL,DTNOW,ISEES,FESLS,DTACC,LLSAV,
     *               LSAVE
      COMMON /COM17/ SS(100),SSL(100),DD(100),DDL(100),LLSVF(100,2)
      COMMON /COM18/ IS(20),NABAD(300),YABAR(600)
      COMMON /COM22/ ITIME,PFIRB
C
      EQUIVALENCE(SS(41),CTIME),(SS(42),ENDSM)
      EQUIVALENCE(SS(21),FPPEX(1)),(SS(26),FPPEY(1))
      EQUIVALENCE(SS(1),TFPPE(1)),(SS(6),TVFPE(1))
      EQUIVALENCE(SS(11),TRUEX(1)),(SS(16),TRUEY(1))
      EQUIVALENCE(SS(31),VFPPX(1)),(SS(36),VFPPY(1))
C
C
C           COMPUTE RPV FLIGHT POSITIONS.
C
      DO 100 I=1,5
      ITX=I+10
      ITY=I+15
      IFX=I+20
      IFY=I+25
      IVX=I+30
      IVY=I+35
      SS(ITX)=SSL(ITX)+SPEED(I)*TXHED(I)*DTNOW
      SS(ITY)=SSL(ITY)+SPEED(I)*TYHED(I)*DTNOW
      SS(IFX)=SSL(IFX)+CSPED*FXHED(I)*DTNOW
      SS(IFY)=SSL(IFY)+CSPED*FYHED(I)*DTNOW
      SS(IVX)=SSL(IVX)+CSPED*VXHED(I)*DTNOW
      SS(IVY)=SSL(IVY)+CSPED*VYHED(I)*DTNOW
  100 CONTINUE
C
C           UPDATE THE CURRENT TIME.
C
      SS(41)=SS(41)+DTNOW
C
      RETURN
      END
```

Figure 6. FORTRAN Listing of Subroutine STATE.

```
      SUBROUTINE MODRF(M,N)
C
      DIMENSION FPPEX(5),FPPEY(5),TRUEX(5),TRUEY(5),VFPPX(5),VFPPY(5)
      DIMENSION TVFPE(5),TFPPE(5)
      COMMON /UCOM1/ CONVF,CONVV,PI
      COMMON /UCOM2/ CSPED,SPEED(5)
      COMMON /UCOM3/ FXHED(5),FYHED(5),TXHED(5),TYHED(5),VXHED(5),VYHED(
     *5)
      COMMON /UCOM4/ IFLY(5),NFPPE(5),NVFPP(5)
      COMMON /UCOM5/ XFPPE(5,20),YFPPE(5,20)
      COMMON /UCOM6/ XLATD(5),XVFPP(20),YVFPP(20)
      COMMON /COM06/ TNOW,TTNEX,MFAD,SEED,ISEED,NCRDR,NPRNT,NPUNCH,
     *               NRNIT,NRENT,MNOC,NDC,NOTN,NNTC
      COMMON /COM16/ AAERR,DTMAX,DTMIN,DTSAV,IITES,LLERR,RRERR,TTLAS,
     *               TTSAV,DTSUG,DTFUL,DTNOW,ISEES,RESLS,DTACC,LLSAV,
     *               LSAVE
      COMMON /COM17/ SS(100),SSL(100),DD(100),DDL(100),LLSVP(100,2)
      COMMON /COM18/ IS(20),NABAD(300),YABAR(600)
      COMMON /COM22/ TTIME,PFIRB
C
      EQUIVALENCE(SS(41),DTIME),(SS(42),ENDSM)
      EQUIVALENCE(SS(21),FPPEX(1)),(SS(26),FPPEY(1))
      EQUIVALENCE(SS(1),TFPPE(1)),(SS(6),TVFPE(1))
      EQUIVALENCE(SS(11),TRUEX(1)),(SS(16),TRUEY(1))
      EQUIVALENCE(SS(31),VFPPX(1)),(SS(36),VFPPY(1))
C
C
C           BRANCH TO THE APPROPRIATE MODERATOR FUNCTION CODE.
C
      GO TO (100,200,300,400,500,600,700),M
C
C           MODERATOR FUNCTION 1.  COMPUTE THE TIME UNTIL THE STATUS
C           INFORMATION IS DISPLAYED.
C
  100 ITIME=TNOW/5.+1.0
      TTIME=FLOAT(ITIME)*5.-TNOW
      RETURN
C
C           MODERATOR FUNCTION 2.  COMPUTE THE TIME UNTIL THE CONSOLE
C           IS PREPARED TO ACCEPT PATCH POINTS.
C
  200 ITIME=TNOW/5.+1.0
      TTIME=FLOAT(ITIME)*5.-TNOW
      RETURN
C
C           MODERATOR FUNCTION 3.  COMPUTE THE TIME UNTIL THE PATCH
C           COMMAND IS SENT TO THE RPV.
C
  300 ITIME=TNOW/5.+2.0
      TTIME=FLOAT(ITIME)*5.-TNOW
      RETURN
C
C           MODERATOR FUNCTION 4.  PROCESS PATCH COMMAND.
C
C                 DETERMINE FLIGHT PATH POINTS.
C
  400 CALL GETIA(1,VALUE)
      I=VALUE
      IP=NVFPP(I)
      IP1=IP+1
```

Figure 7(1). FORTRAN Listing of Subroutine MODRF.

```
      IP2=IP+2
C
C               DETERMINE PATCH POINT.
C
      CALL GETIA(3,X)
      CALL GETIA(4,Y)
C
C               COMPUTE THE NEW FLIGHT PATH.
C
      DOLD=SQRT(((VFPPX(I)-X)**2)+((VFPPY(I)-Y)**2))
      DNEW=SQRT(((TRUEX(I)-X)**2)+((TRUEY(I)-Y)**2))
      VFPPX(I)=VFPPX(I)+(DOLD-DNEW)*VXHED(I)
      VFPPY(I)=VFPPY(I)+(DOLD-DNEW)*VYHED(I)
      TVFPE(I)=TVFPE(I)-(DOLD-DNEW)/CSPED
      FPPEX(I)=TRUEX(I)
      FPPEY(I)=TRUEY(I)
      XFPPE(I,IP1)=X
      YFPPE(I,IP1)=Y
      XFPPE(I,IP2)=TRUEX(I)
      YFPPE(I,IP2)=TRUEY(I)
      NFPPE(I)=IP2
      GO TO 620
C
C          MODERATOR FUNCTION 5.  PROCESS FRAME UPDATE INFORMATION.
C
  500 I=1
      ITNO=TNOW
  510 IF(IFLY(I).EQ.0) GO TO 550
      IF(VXHED(I).EQ.0.) GO TO 520
      IF(VYHED(I).EQ.0.) GO TO 530
C
C               COMPUTE FLIGHT PATH DEVIATIONS.
C
      X=(TRUEY(I)+(VXHED(I)/VYHED(I))*TRUEX(I)-VFPPY(I)+(VYHED(I)/VXHED(
     *I))*VFPPX(I))/(VYHED(I)/VXHED(I)+VXHED(I)/VYHED(I))
      Y=(VYHED(I)/VXHED(I))*X+VFPPY(I)-(VYHED(I)/VXHED(I))*VFPPX(I)
      XLATD(I)=SQRT((TRUEX(I)-X)**2+(TRUEY(I)-Y)**2)
      SPDEV=SQRT((VFPPX(I)-X)**2+(VFPPY(I)-Y)**2)
      GO TO 540
  520 XLATD(I)=TRUEX(I)-VFPPX(I)
      SPDEV=TRUEY(I)-VFPPY(I)
      IF(XLATD(I).LT.0.) XLATD(I)=-XLATD(I)
      IF(SPDEV.LT.0.) SPDEV=-SPDEV
      GO TO 540
  530 XLATD(I)=VFPPY(I)-TRUEY(I)
      SPDEV=VFPPX(I)-TRUEX(I)
      IF(XLATD(I).LT.0.) XLATD(I)=-XLATD(I)
      IF(SPDEV.LT.0.) SPDEV=-SPDEV
C
C               COLLECT FLIGHT PATH DEVIATIONS.
C
  540 CALL UCLCT(XLATD(I),2)
      CALL UHIST(XLATD(I),2)
      CALL UCLCT(SPDEV,3)
      CALL UHIST(SPDEV,3)
C
C               REPORT FLIGHT STATUS FOR THIS RPV.
C
C
C
C               CONSIDER NEXT RPV.
C
```

Figure 7(2). FORTRAN Listing of Subroutine MODRF.

```
  550 I=I+1
      IF(I.LE.5) GO TO 510
      RETURN
C
C
C          MODERATOR FUNCTION 6.  PROCESS FPPE TURN.
C
C                 CAUSE FPPE TO HEAD TOWARDS THE NEXT FLIGHT PATH POINT.
C
  600 I=IS(1)
      IFLY(I)=1
  620 IP=NFPPE(I)
      IF(IP.EQ.1) GO TO 650
      J=IP-1
      DX=XFPPE(I,J)-XFPPE(I,IP)
      DY=YFPPE(I,J)-YFPPE(I,IP)
      D=SQRT(DX**2+DY**2)
      FXHED(I)=DX/D
      FYHED(I)=DY/D
      TFPPE(I)=TNOW+D/CSPED
      NFPPE(I)=NFPPE(I)-1
      AY=ASIN(FYHED(I))
      IF(FXHED(I).LT.0.) AY=PI-AY
      AY=AY+RNORM(5)
      TXHED(I)=COS(AY)
      TYHED(I)=SIN(AY)
      SPEED(I)=CSPED+RNORM(7)*CONVV
      RETURN
C
C                 CAUSE RPV TO END FLIGHT.  COMPUTE RPV DISTANCE FROM
C                 TARGET.
C
  650 TXHED(I)=0.
      TYHED(I)=0.
      FXHED(I)=0.
      FYHED(I)=0.
      VXHED(I)=0.
      VYHED(I)=0.
      TFPPE(I)=99999.
      TVFPE(I)=99999.
      DX=TRUEX(I)-VFPPX(I)
      DY=TRUEY(I)-VFPPY(I)
      D=SQRT(DX**2+DY**2)
      CALL UCLCT(D,1)
      CALL UHIST(D,1)
      IFLY(I)=0
      DO 660 I=1,5
      IF(IFLY(I).EQ.1) RETURN
  660 CONTINUE
C
C                 ALL RPVS HAVE REACHED TARGET.  END SIMULATION.
C
      ENDSM=2.
      RETURN
C
C          MODERATOR FUNCTION 7.  PROCESS VFPPE TURN.
C
C                 CAUSE VFPPE TO MOVE TOWARDS THE NEXT FLIGHT PATH POINT.
C
  700 I=IS(2)
      IP=NVFPP(I)
```

Figure 7(3). FORTRAN Listing of Subroutine MODRF.

```
      IF(IP.EQ.1) RETURN
      J=IP-1
      DX=XVFPP(J)-XVFPP(IP)
      DY=YVFPP(J)-YVFPP(IP)
      D=SQRT(DX**2+DY**2)
      VXHED(I)=DX/D
      VYHED(I)=DY/D
      TVFPE(I)=TNOW+D/CSPED
      NVFPP(I)=NVFPP(I)-1
      RETURN
C
      END
```

Figure 7(4). FORTRAN Listing of Subroutine MODRF.

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```
      FUNCTION USERF(M)
C
      DIMENSION FPPEX(5),FPPEY(5),TRUEX(5),TRUEY(5),VFPPX(5),VFPPY(5)
      DIMENSION TVFPE(5),TFPPE(5)
      COMMON /UCOM1/ CONVF,CONVV,PI
      COMMON /UCOM2/ CSPED,SPEED(5)
      COMMON /UCOM3/ FXHED(5),FYHED(5),TXHED(5),TYHED(5),VXHED(5),VYHED(
     *5)
      COMMON /UCOM4/ IFLY(5),NFPPE(5),NVFPP(5)
      COMMON /UCOM5/ XFPPE(5,20),YFPPE(5,20)
      COMMON /UCOM6/ XLATD(5),XVFPP(20),YVFPP(20)
      COMMON /COM06/ TNOW,TTNEX,MFAD,SEED,ISEED,NCRDR,NPRNT,NPUNCH,
     *               NRNIT,NRENT,MNDC,NDC,NCTN,NNTC
      COMMON /COM16/ AAERR,DTMAX,DTMIN,DTSAV,IITES,LLERR,RRERR,TTLAS,
     *               TTSAV,DTSUG,DTFUL,DTNOW,ISEES,RESLS,DTACC,LLSAV,
     *               LSAVE
      COMMON /COM17/ SS(100),SSL(100),DD(100),DDL(100),LLSVR(100,2)
      COMMON /COM18/ IS(20),NABAD(300),YABAR(500)
      COMMON /COM22/ TTIME,PFIRS
C
      EQUIVALENCE(SS(41),CTIME),(SS(42),ENDSM)
      EQUIVALENCE(SS(21),FPPEX(1)),(SS(26),FPPEY(1))
      EQUIVALENCE(SS(1),TFPPE(1)),(SS(6),TVFPE(1))
      EQUIVALENCE(SS(11),TRUEX(1)),(SS(16),TRUEY(1))
      EQUIVALENCE(SS(31),VFPPX(1)),(SS(36),VFPPY(1))
C
C
C           BRANCH TO THE APPROPRIATE USER FUNCTION CODE.
C
      GO TO (100,200,300,400,500),M
C
C           USER FUNCTION 1.  DETERMINE THE NUMBER OF THE NEXT RPV
C           TO BE CONSIDERED.
C
  100 CALL GETIA(1,VALUE)
      IF(ENDSM.GT.0.) GO TO 120
      I=VALUE
      IF(I.EQ.0) GO TO 120
  110 I=I+1
      IF(I.GT.5) GO TO 130
      IF(IFLY(I).EQ.0) GO TO 110
      USERF=I
      RETURN
  120 USERF=1.0
      RETURN
  130 I=0
      GO TO 110
C
C           USER FUNCTION 2.  DETERMINE IF THE LATERAL DEVIATION
C           OF THIS RPV IS LARGE ENOUGH TO CAUSE THE OPERATOR TO PATCH.
C
  200 CALL GETIA(1,VALUE)
      I=VALUE
      USERF=0.
      CALL GETRA(1,1,VALUE)
      IF(XLATD(I).GE.VALUE) USERF=1.0
      RETURN
C
C           USER FUNCTION 3.  DETERMINE IF THE OPERATOR WILL PATCH
C           THIS RPV.
```

Figure 8(1). FORTRAN Listing of Function USERF.

```
C
  300 CALL GETRA(1,2,VALUE)
      USERF=0.
      XX=DRAND(ISEED)
      IF(VALUE.GT.XX) USERF=1.0
      RETURN
C
C             USER FUNCTION 4.  DETERMINE IF A TURN PREVENTS PATCHING.
C
  400 USERF=1.0
      CALL GETIA(1,VALUE)
      I=VALUE
      DIST=(TVFPE(I)-TNOW)*CSPED/CONVF
      IF(DIST.LT.5.0) USERF=0.
      RETURN
C
C             USER FUNCTION 5.  SET THE COORDINATES OF THE PATCH POINT
C             IN INFORMATION ATTRIBUTES.
C
  500 DIST=3.0*CONVF
      CALL GETIA(1,VALUE)
      I=VALUE
      X=VFPPX(I)+DIST*VXHED(I)
      Y=VFPPY(I)+DIST*VYHED(I)
      CALL PUTIA(3,X)
      CALL PUTIA(4,Y)
      RETURN
      END
```

Figure 8(2). FORTRAN Listing of Function USERF.

SECTION VI

SPSS ANALYSIS

As indicated previously, the effort reported herein is designed to illustrate the interface of output from a SAINT simulation with the SPSS statistical routines. The model analyzed has been kept relatively simple to facilitate the discussion of this interface. The following discussions emphasize the procedures and FORTRAN coding required to achieve the SAINT-SPSS interface. They do not provide detailed information on SPSS capabilities, statistical procedures, or SAINT modeling. The interested reader is referred to the references cited in this report for detailed discussions on these topics. In addition, this analysis is not intended to fully define all the possible interface capabilities nor is it intended to be as complete and precise an analysis as one that would be done with a SAINT model of a real-world system. Again, the analysis is solely intended to illustrate the methodology required for a SAINT-SPSS interface.

Analysis of Variance

The first analysis is designed to determine if there is a statistically significant difference between navigation systems (A and B) and between the two levels of the control criterion (0 and 1000 feet) in terms of the average linear distance that the five RPVs are from the target at the time they deliver their payload (hereafter referred to as "average linear distance"). Four replications (iterations) of each combination of navigation system/control criterion were made. The significance level for the test is 0.05. The ANOVA model for this analysis is given below:

$$y_{ijk} = \mu + N_i + C_j + NC_{ij} + \varepsilon_{(ij)k}$$

$$i=1,2 \quad j=1,2 \quad k=1,2,3,4$$

where

μ = overall mean

N_i = effect of the ith navigation system

C_j = effect of the jth control criterion

NC_{ij} = effect of the interaction of the ith navigation system with the jth control criterion

$\varepsilon_{(ij)k}$ = within error of the kth average linear distance in the ith navigation system and jth control criterion setting

In order to perform this analysis, the parameters (navigation system and control criterion) must be set for each iteration of the model, the appropriate statistics must be collected from each iteration, and the information collected must be output in a form consistent with SPSS input requirements. The FORTRAN code in subroutine ENDIT performs all of these functions.

Parameter Definitions

Subroutine ENDIT is called automatically by SAINT at the end of each iteration. It is called with one integer argument, the number of the iteration that was just completed. Subroutine ENDIT, which is user-coded will process information based on this iteration number.

For this analysis, the sixteen iterations that were performed are defined below:

Iteration Number	Navigation System	Control Criterion
1-4	A	0
5-8	B	0
9-12	A	1000
13-16	B	1000

Initially, SAINT data input defines the system as employing navigation system A and control criterion 0. At the end of iteration 4, ENDIT changes the navigation system to B. After iteration 8, it causes navigation systems A and control criterion 1000 to be used. After iteration 12, it changes the navigation system back to B.

In the model, the navigation system is defined by distribution sets 6 and 7. Distribution set 6 defines the ground course error of the navigation system; distribution set 7 defines the ground speed error. The means of these distributions for both navigation systems are 0. Thus,

ENDIT need only alter the standard deviations of these distributions to model different navigation systems. Since both distributions are normal, SAINT variables PARAM(6,4) and PARAM(7,4) define the standard deviations of distribution sets 6 and 7, respectively. Therefore, when required to change a navigation system, ENDIT resets the values of PARAM(6,4) and PARAM(7,4). These variables remain at the assigned values until ENDIT again changes them.

ENDIT changes the control criterion used for each iteration in a similar fashion. The control criterion is defined in distribution set 8. Since this distribution is constant, SAINT variable PARAM(8,1) represents the control criterion. It is reset when required by ENDIT.

The values assigned to the above mentioned variables are summarized below:

Iteration Number	PARAM(6,4)	PARAM(7,4)	PARAM(8,1)
1-4	0.035	10.0	0.0
5-8	0.005	2.0	0.0
9-12	0.035	10.0	1000.0
13-16	0.005	2.0	1000.0

SPSS Format

Subroutine ENDIT will produce a file of output (file NOTPT) that will serve as input to the SPSS statistical routines. Input to SPSS generally follows the form:

SPSS CONTROL CARDS
SPSS PROCEDURE CARDS
DATA INPUT
FINISH CARD

Subroutine ENDIT must produce output in this format. For this reason, when ENDIT is called after the first iteration, it produces the SPSS control and procedure card file prior to processing data. Additionally, ENDIT processes the FINISH card after processing the data for the last iteration. The SPSS control cards will not be discussed in this report. They are fully described in reference material [1].

Data Input

After each iteration, ENDIT outputs to file NOTPT the data necessary for the SPSS analysis. For each iteration, one card is prepared which contains the following information:

Data Card Columns	Value
1-10	Average linear deviation
11-15	Navigation system code 1 = A 2 = B
16-20	Control Criterion code 1 = 0 feet 2 = 1000 feet

Subroutine ENDIT determines the appropriate values for the iteration and then outputs them in the above format. The navigation system and control criterion codes are determined directly from the iteration number. However, the linear deviation requires some calculation.

For each iteration, the deviation of each RPV from the target at the time it delivers its payload is collected in user-statistic 1, using calls to subroutine UCLCT. When ENDIT is called, the SAINT variables for user-statistic 1 contains the following values:

Variable	Value
USOBV(1,1)	The sum of the deviation of the five RPVs
USOBV(1,2)	The sum of the squares of the deviations of the five RPVs
USOBV(1,3)	The number of observations
USOBV(1,4)	The minimum deviation observed
USOBV(1,5)	The maximum deviation observed

To compute the average value, ENDIT divides USOBV(1,1) by USOBV(1,3).

The last function of subroutine ENDIT is to report the user-statistics collected and to clear the storage for the

next iteration. Reporting is performed through calls to subroutines UCLCT and UHIST with second arguments of zero. Clearing is performed through subroutine CLEAR.

The FORTRAN listing of subroutine ENDIT for the ANOVA performed is given in Figure 9.

Results

The SAINT model was executed for the sixteen iterations discussed above. The output written to file NOTPT is presented in Figure 10. This output is directly input to the SPSS statistical routines for analysis. The job control language for linking the data file with the SPSS routines is dependent on the computer installation used and is not presented here. The SPSS documentation (1) illustrates how this is done for a variety of computers.

The results of the SPSS ANOVA analysis are given in Figure 11. These results show that the navigation system effect (NAVSYS) is significant at the .001 level, that the control criterion effect (NPATCH) is significant at the .001 level, and that the interaction effect (NAVSYS by NPATCH) is significant at the .999 level. Since the level of significance was set at .05, the following conclusions were made:

1. There is a statistically significant difference in terms of mission performance, between navigation systems A and B.

2. There is a statistically significant difference, in terms of mission performance, between control criteria 0 and 1000.

3. There is no significant interaction effect between navigation system and control criterion.

Since there is a statistically significant improvement in mission performance when navigation system B is used instead of A, the inertial navigation system (B) will be selected for the RPVs and will be used for the remainder of this analysis. The selection of a control criterion will be analyzed further.

Scattergram Analysis

From the ANOVA analysis above, there is a statistically significant difference, in terms of mission performance,

```
      SUBROUTINE ENDIT(ITER)
      COMMON /COM09/ PARAM(100,5),NPTBU(100),PARM1(100),PARM4(100)
      COMMON /COM23/ LLUGC(20,2),USOBV(20,5),LLUGT(20,2),TTCLR(20),
     *               USTPV(20,5),LLUGH(20,2),NNCEL(20),HHLOW(20),
     *               HHWID(20),JJCEL(540)
C
C     NOTPT  SPECIFIES THE CARD PUNCH NUMBER
C
      NOTPT=7
      IF(ITER.GT.1) GO TO 500
C
C           WRITE SPSS CONTROL CARDS.
C
      WRITE(NOTPT,100)
      WRITE(NOTPT,101)
      WRITE(NOTPT,102)
      WRITE(NOTPT,103)
      WRITE(NOTPT,104)
      WRITE(NOTPT,105)
      WRITE(NOTPT,106)
  100 FORMAT(8HRUN NAME,7X,20HSAINT-SPSS EXAMPLE 1)
  101 FORMAT(13HVARIABLE LIST,2X,20HTARGET NAVSYS NPATCH)
  102 FORMAT(12HINPUT MEDIUM,3X,4HCARD)
  103 FORMAT(10HN OF CASES,5X,2H16)
  104 FORMAT(12HINPUT FORMAT,3X,23HFIXED (F10.3,F5.0,F5.0))
  105 FORMAT(5HANOVA,10X,34HTARGET BY NAVSYS(1,2) NPATCH(1,2)/)
  106 FORMAT(10HREAD INPUT)
  107 FORMAT(6HFINISH)
C
C           DETERMINE NAVIGATION SYSTEM TYPE AND CONTROL STRATEGY
C           USED FOR THE LAST ITERATION.
C
  500 GO TO (1,1,1,1,2,2,2,2,3,3,3,3,4,4,4,4),ITER
    1 NAVS=1
      NPAT=1
      GO TO 5
    2 NAVS=2
      NPAT=1
      GO TO 5
    3 NAVS=1
      NPAT=2
      GO TO 5
    4 NAVS=2
      NPAT=2
C
C           COMPUTE THE AVERAGE LINEAR DISTANCE FROM THE TARGET FOR
C           THIS ITERATION AND PRINT OUT THE SPSS DATA CARD FOR THIS
C           ITERATION.
C
    5 AVG=USOBV(1,1)/USOBV(1,3)
      WRITE(NOTPT,108) AVG,NAVS,NPAT
  108 FORMAT(F10.3,I5,I5)
C
C           CAUSE SAINT TO REPORT ON ALL USER COLLECTED STATISTICS
C           FOR THIS ITERATION.  CLEAR THESE STATISTICAL STORAGE
C           ARRAYS FOR THE NEXT ITERATION.
C
      CALL UCLCT(1.,0)
      CALL UHIST(1.,0)
      CALL CLEAR
C
C           SET THE PARAMETER VALUES THAT ARE APPLICABLE FOR THE
C           NEXT ITERATION.  PRINT OUT THE SPSS *FINISH* CARD IF
```

Figure 9(1). FORTRAN Listing of Subroutine ENDIT for the ANOVA Analysis.

```
C      THIS WAS THE LAST ITERATION.
C
       GO TO (10,10,10,6,10,10,10,7,10,10,10,8,10,10,10,9),ITER
     6 PARAM(6,4)=0.005
       PARAM(7,4)=2.0
       GO TO 10
     7 PARAM(6,4)=0.035
       PARAM(7,4)=10.0
       PARAM(8,1)=1000.
       GO TO 10
     8 PARAM(6,4)=0.005
       PARAM(7,4)=2.0
       GO TO 10
     9 WRITE(NOTFT,107)
    10 RETURN
       END
```

Figure 9(2). FORTRAN Listing of Subroutine ENDIT for the ANOVA Analysis.

```
RUN NAME        SAINT-SPSS EXAMPLE 1
VARIABLE LIST   TARGET NAVSYS NPATCH
INPUT MEDIUM    CARD
N OF CASES      16
INPUT FORMAT    FIXED (F10.3,F5.0,F5.0)
ANOVA           TARGET BY NAVSYS(1,2) NPATCH(1,2)/
READ INPUT
  1047.500    1    1
  1670.297    1    1
  1268.520    1    1
   901.908    1    1
   142.816    2    1
   303.953    2    1
   167.439    2    1
   232.121    2    1
  1577.890    1    2
  3167.620    1    2
  1681.168    1    2
  2131.221    1    2
  1595.286    2    2
   676.767    2    2
  1042.972    2    2
   595.364    2    2
FINISH
```

Figure 10. Listing of Output Written to File NOTPT for the ANOVA Analysis.

SAINT-SPSS EXAMPLE 1

FILE NONAME (CREATION DATE = 07/02/76.)

* * * * * * * * * * * A N A L Y S I S   O F   V A R I A N C E * * * * * * * * * * *

TARGET
BY NAVSYS
NPATCH

* *

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	7509206.145	2	3754603.073	18.268	.001
NAVSYS	4504397.113	1	4504397.113	21.916	.001
NPATCH	3004809.033	1	3004809.033	14.620	.003
2-WAY INTERACTIONS	10283.684	1	10283.684	.050	.999
NAVSYS NPATCH	10283.684	1	10283.684	.050	.999
RESIDUAL	2466312.258	12	205526.022		
TOTAL	9985802.089	15	665720.139		

16 CASES WERE PROCESSED.
0 CASES (0 PCT) WERE MISSING.

Figure 11. Results of the SPSS ANOVA Analysis.

between control criteria 0 and 1000. To examine the control criterion question more closely, an SPSS SCATTERGRAM analysis was performed. The inertial navigation system was used in performing four replications of five different control criteria. The twenty iterations are defined as follows:

Iteration Number	Control Criterion
1-4	0
5-8	250
9-12	500
13-16	750
17-20	1000

In a manner similar to the ANOVA analysis, subroutine ENDIT defines the parameters for each iteration, prepares the SPSS control cards, and creates the SPSS data input file.

Parameter Definitions

Since the control criterion is the only parameter that can change between iterations, subroutine ENDIT changes only PARAM(8,1), the SAINT variable defining the control criterion. The value is input as 0 and ENDIT changes it to 250, 500, 750, and 1000 after iterations 4, 8, 12, and 16, respectively.

SPSS Format

The control cards for SPSS for the scattergram analysis are prepared in the same manner as those of the ANOVA analysis.

Data Input

The data input for the scattergram analysis is computed and output to file NOTPT after each iteration. For each iteration, one data card is prepared which contains the following information:

Data Card Columns	Value
1-10	Average linear deviation
11-15	Control criterion

Subroutine ENDIT determines the appropriate values for the iteration and then outputs them in SPSS format. The appropriate level for the control criterion is determined directly from the iteration number. The average linear deviation, as before, is computed by dividing USOBV(1,1) by USOBV(1,3).

Subroutine ENDIT also reports and clears the statistical storage arrays. The FORTRAN listing of subroutine ENDIT for the scattergram analysis is given in Figure 12.

Results

The SAINT model was executed for the twenty iterations discussed above. The output written to file NOTPT is presented in Figure 13. This output is then directly input to the SPSS statistical routines for analysis.

The results of the SPSS scattergram analysis is given in Figure 14. The average linear distance from the target is plotted against the control criterion used. These results indicate that mission performance deteriorates as the control criterion is increased. Assuming that an average of 350 feet of deviation is acceptable, the following table presents the percentage of iterations whose performance was acceptable for each control criterion.

Control Criterion	Percent Acceptable
0	100
250	50
500	25
750	0
1000	0

Since the mission requires approximately ten minutes from start to completion (all RPVs have achieved target), it does not seem excessive to require that the operator patch the RPVs continuously. And since the above results indicate that mission performance will be significantly improved by this procedure, this procedure will be employed. Therefore, the RPV system definition now includes the use of navigation system B and control criterion 0. Further analysis will only be performed using this system.

```
      SUBROUTINE ENDIT(ITER)
      COMMON /CCM09/ PARAM(100,5),NPTBU(100),PARM1(100),PARM2(100)
      COMMON /CCM23/ LLUGC(20,2),USOBV(20,5),LLUGT(20,2),TTCLR(20),
     *               USTPV(20,5),LLUGH(20,2),NNCEL(20),HHLOW(20),
     *               HHWID(20),JJCEL(540)
      NOTPT=7
      IF(ITER.GT.1) GO TO 500
C
C          WRITE SPSS CONTROL CARDS.
C
      WRITE(NOTPT,100)
      WRITE(NOTPT,101)
      WRITE(NOTPT,102)
      WRITE(NOTPT,103)
      WRITE(NOTPT,104)
      WRITE(NOTPT,105)
      WRITE(NOTPT,106)
  100 FORMAT(8HRUN NAME,7X,20HSAINT-SPSS EXAMPLE 2)
  101 FORMAT(13HVARIABLE LIST,2X,13HTARGET NPATCH)
  102 FORMAT(12HINPUT MEDIUM,3X,4HCARD)
  103 FORMAT(10HN OF CASES,5X,2H20)
  104 FORMAT(12HINPUT FORMAT,3X,18HFIXED (F10.3,F5.0))
  105 FORMAT(11HSCATTERGRAM,4X,39HTARGET(0.,2000.) WITH NPATCH(0.,1000.)
     */)
  106 FORMAT(10HREAD INPUT)
  107 FORMAT(6HFINISH)
C
C          DETERMINE CONTROL CRITERION
C          USED FOR THE LAST ITERATION.
C
  500 GO TO (1,1,1,1,2,2,2,2,3,3,3,3,4,4,4,4,5,5,5,5),ITER
    1 NPAT=0
      GO TO 6
    2 NPAT=250
      GO TO 6
    3 NPAT=500
      GO TO 6
    4 NPAT=750
      GO TO 6
    5 NPAT=1000
C
C          COMPUTE THE AVERAGE LINEAR DISTANCE FROM THE TARGET FOR
C          THIS ITERATION AND PRINT OUT THE SPSS DATA CARD FOR THIS
C          ITERATION.
C
    6 AVG=USOBV(1,1)/USOBV(1,3)
      WRITE(NOTPT,108) AVG,NPAT
  108 FORMAT(F10.3,I5)
C
C          CAUSE SAINT TO REPORT ON ALL USER COLLECTED STATISTICS
C          FOR THIS ITERATION.  CLEAR THESE STATISTICAL STORAGE
C          ARRAYS FOR THE NEXT ITERATION.
C
      CALL UCLCT(1.,0)
      CALL UHIST(1.,0)
      CALL CLEAR
C
C          SET THE PARAMETER VALUES THAT ARE APPLICABLE FOR THE
C          NEXT ITERATION.  PRINT OUT THE SPSS *FINISH* CARD IF
C          THIS WAS THE LAST ITERATION.
```

Figure 12(1). FORTRAN Listing of Subroutine ENDIT for the Scattergram Analysis.

```
C
      GO TO (15,15,15,10,15,15,15,11,15,15,15,12,15,15,15,13,15,15,15,14
     *),ITER
   10 PARAM(8,1)=250.
      GO TO 15
   11 PARAM(8,1)=500.
      GO TO 15
   12 PARAM(8,1)=750.
      GO TO 15
   13 PARAM(8,1)=1000.
      GO TO 15
   14 WRITE(NOTPT,107)
   15 RETURN
      END
```

Figure 12(2). FORTRAN Listing of Subroutine ENDIT for the Scattergram Analysis.

```
RUN NAME         SAINT-SPSS EXAMPLE 2
VARIABLE LIST    TARGET NPATCH
INPUT MEDIUM     CARD
N OF CASES       20
INPUT FORMAT     FIXED (F10.3,F5.0)
SCATTERGRAM      TARGET(0.,2000.) WITH NPATCH(0.,1000.)/
READ INPUT
   320.784    0
   240.566    0
   234.272    0
   181.926    0
   235.359  250
   682.232  250
   758.978  250
   199.553  250
   289.374  500
   413.473  500
  1122.990  500
   390.421  500
   718.965  750
   615.705  750
  1242.892  750
   780.895  750
   577.269 1000
   775.692 1000
   839.246 1000
   672.964 1000
FINISH
```

Figure 13. Listing of Output Written to File NOTPT for the Scattergram Analysis.

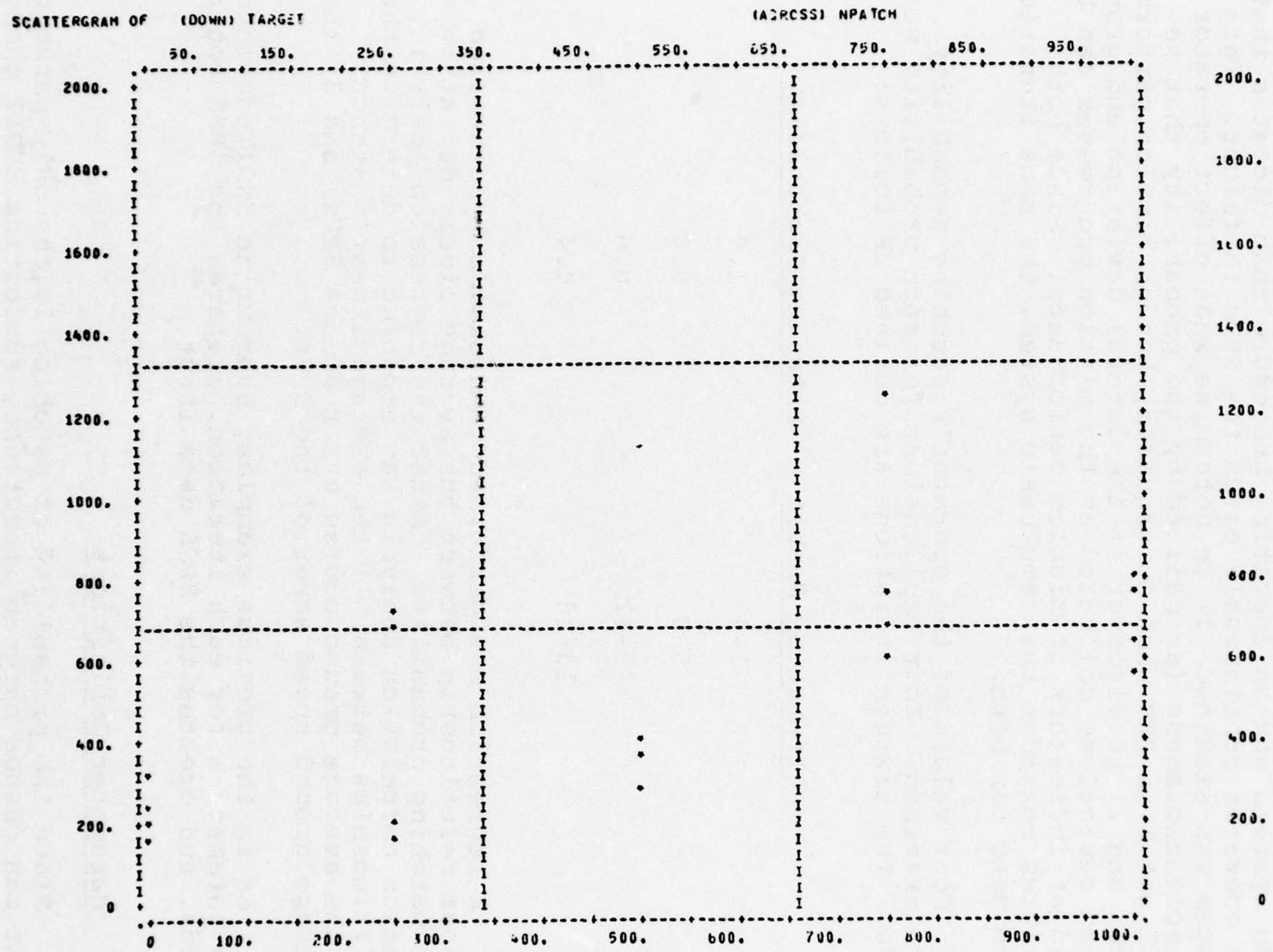

Figure 14. Results of the SPSS Scattergram Analysis.

Regression and Correlation Analyses

The analyses performed above have determined that the RPV system will be composed of RPVs with inertial navigation systems and an operating procedure that dictates that the operator continuously patch the RPVs in flight. This system was examined 1) to determine what effect operator conscientiousness (as defined by the probability that he will patch an RPV when so required) has on mission performance; and 2) to discover if the lateral deviation and ground speed deviations collected as the mission progresses can be used as indicators of mission performance. Since both analyses consider the same basic system, the same iterations were used for both.

Four values of the operator's patching probability were examined. Four replications for each probability were made. The sixteen iterations are defined as follows:

Iteration Number	Patching Probability
1-4	1.0
5-8	0.8
9-12	0.6
13-16	0.4

A regression was performed to assess a hypothesized linear relationship between the average linear deviation and the patching probability. After the regression analysis, a Pearson correlation analysis was employed to determine the relationships between 1) the average linear distance, 2) the average ground course error of the RPVs, and 3) the average ground speed error of the RPVs.

As in the previous examples, Subroutine ENDIT defines the parameters for each iteration, prepares the SPSS control cards, and creates the SPSS data input.

Parameter Definitions

Since the probability of patching is the only parameter that can change between iterations, subroutine ENDIT changes only PARAM(5,1), the SAINT variable defining the probability of patching. The value is input as 1.0 and ENDIT changes the value to 0.8, 0.6, and 0.4 after iterations 4, 8, and 12, respectively.

SPSS Format

Since two analyses were performed using the same data set, the SPSS control cards were printed in a different order than previously used. The procedure cards for the second analysis to be performed follow the data input. Thus, subroutine ENDIT processes the SPSS control cards and the SPSS procedure cards for the regression analysis after the first iteration. The procedure cards for the Pearson correlation are processed after the last iteration (just prior to the FINISH card).

Data Input

The data required for both analyses performed is output to file NOTPT at the end of each iteration. The data card prepared for each iteration is of the following format:

Data Card Columns	Value
1-10	Average linear deviation
11-20	Patching probability
21-30	Average ground course error
31-40	Average ground speed error

Subroutine ENDIT determines the appropriate values for the iteration and then outputs them in the above format. The patching probability is determined directly from the iteration number. The other values require calculation by subroutine ENDIT.

For each iteration, the deviation of each RPV from the target at the time it delivers its payload is collected in user-statistic 1. The ground course and ground speed errors of all RPVs are collected every five seconds in user-statistics 2 and 3, respectively. Since SAINT variables USOBV(I,1) and USOBV(I,3) represent, respectively, the sum of the observations collected and the number of observations collected for user-statistic I, the average values are computed by:

$$\text{Average} = \frac{\text{USOBV(I,1)}}{\text{USOBV(I,3)}}$$

As in the previous analyses, subroutine ENDIT also reports the user-collected statistics and clears the statistical storage for the next iteration. The FORTRAN listing of subroutine ENDIT for the regression and correlation analyses is given in Figure 15.

SAINT Output

The SAINT model was executed for the sixteen iterations discussed above. The output written to file NOTPT is presented in Figure 16. This output is input to the SPSS statistical routines for analysis.

Regression Results

The results of the SPSS regression analysis are given in Figure 17. If there is a linear relationship between the average linear distance and the probability of patching (between the range of 0.4 and 1.0), then the best estimate of this relation is:

$$TARGET = 462 - 252 * PPATCH$$

where:

TARGET = average linear distance

PPATCH = probability of patching.

The results indicate that there is a statistically significant difference, in terms of mission performance, between patching probabilities (level = .024) and that there is a 95 percent confidence that the coefficient of PATCH is between -466 and -39. Thus, mission performance improves (TARGET increases) as operator conscientiousness (as defined by the probability of patching) increases.

The results also estimate that 32 percent (R SQUARE) of the variation in TARGET is explained by PATCH. If the assumption of a linear relation between TARGET and PPATCH is correct, the analysis of our model's output suggests that 68 percent of the variation in TARGET is caused by the randomness inherent in the system (the random variation of the navigation systems).

```
      SUBROUTINE ENDIT(ITER)
      COMMON /CCM09/ PARAM(100,5),NPTBU(100),PARM1(100),PARM4(100)
      COMMON /CCM23/ LLUGC(20,2),USOBV(20,5),LLUGT(20,2),TTCLR(20),
     *               USTPV(20,6),LLUGH(20,2),NNCEL(20),HHLOW(20),
     *               HHWID(20),JJCEL(540)
      NOTPT=7
      IF(ITER.GT.1) GO TO 500
C
C         WRITE SPSS CONTROL CARDS.
C
      WRITE(NOTPT,100)
      WRITE(NOTPT,101)
      WRITE(NOTPT,102)
      WRITE(NOTPT,103)
      WRITE(NOTPT,104)
      WRITE(NOTPT,105)
      WRITE(NOTPT,110)
      WRITE(NOTPT,109)
      WRITE(NOTPT,106)
  100 FORMAT(8HRUN NAME,7X,20HSAINT-SPSS EXAMPLE 3)
  101 FORMAT(13HVARIABLE LIST,2X,24HTARGET PPATCH GORS GSPED)
  102 FORMAT(12HINPUT MEDIUM,3X,4HCARD)
  103 FORMAT(10HN OF CASES,5X,2H16)
  104 FORMAT(12HINPUT FORMAT,3X,31HFIXED (F10.3,F10.3,F10.3,F10.3))
  105 FORMAT(10HREGRESSION,5X,26HVARIABLES = TARGET PPATCH/)
  109 FORMAT(10HSTATISTICS,5X,3HALL)
  110 FORMAT(15X,35HREGRESSION = TARGET WITH PPATCH(2)/)
  106 FORMAT(10HREAD INPUT)
  107 FORMAT(6HFINISH)
C
C         DETERMINE OPERATOR PATCHING PROBABILITY
C         USED FOR THE LAST ITERATION.
C
  500 GO TO (1,1,1,1,2,2,2,2,3,3,3,3,4,4,4,4),ITER
    1 PPATCH=1.0
      GO TO 5
    2 PPATCH=0.8
      GO TO 5
    3 PPATCH=0.6
      GO TO 5
    4 PPATCH=0.4
C
C         COMPUTE THE AVERAGE LINEAR DISTANCE FROM THE TARGET FOR
C         THIS ITERATION AND PRINT OUT THE SPSS DATA CARD FOR THIS
C         ITERATION.
C
    5 AVG=USOBV(1,1)/USOBV(1,3)
      AVG1=USOBV(2,1)/USOBV(2,3)
      AVG2=USOBV(3,1)/USOBV(3,2)
      WRITE(NOTPT,108) AVG,PPATCH,AVG1,AVG2
  108 FORMAT(4F10.3)
C
C         CAUSE SAINT TO REPORT ON ALL USER COLLECTED STATISTICS
C         FOR THIS ITERATION.  CLEAR THESE STATISTICAL STORAGE
C         ARRAYS FOR THE NEXT ITERATION.
C
      CALL UCLST(1.,0)
      CALL UHIST(1.,0)
      CALL CLEAR
C
```

Figure 15(1). FORTRAN Listing of Subroutine ENDIT for the Regression and Correlation Analyses.

```
C           SET THE PARAMETER VALUES THAT ARE APPLICABLE FOR THE
C           NEXT ITERATION.  PRINT OUT THE SPSS *FINISH* CARD IF
C           THIS WAS THE LAST ITERATION.
C
      GO TO (10,10,10,6,10,10,10,7,10,10,10,8,10,10,10,9),ITER
    6 PARAM(5,1)=0.6
      GO TO 10
    7 PARAM(5,1)=0.5
      GO TO 10
    8 PARAM(5,1)=0.4
      GO TO 10
    9 WRITE(NOTPT,112)
      WRITE(NOTPT,111)
      WRITE(NOTPT,109)
      WRITE(NOTPT,107)
  112 FORMAT(12HPEARSON CORR,3X,40HTARGET GCRS GSPED WITH TARGET GCRS GS
     *PED)
  111 FORMAT(7HOPTIONS,8X,1H3)
   10 RETURN
      END
```

Figure 15(2). FORTRAN Listing of Subroutine ENDIT for the Regression and Correlation Analyses.

```
RUN NAME          SAINT-SPSS EXAMPLE 3
VARIABLE LIST     TARGET PPATCH GCRS GSPED
INPUT MEDIUM      CARD
N OF CASES        16
INPUT FORMAT      FIXED (F10.3,F10.3,F10.3,F10.3)
REGRESSION        VARIABLES = TARGET PPATCH/
                  REGRESSION = TARGET WITH PPATCH(2)/
STATISTICS        ALL
READ INPUT
    320.784       1.000     93.019         .008
    240.586       1.000     59.350         .007
    234.272       1.000     97.526         .006
    181.926       1.000     95.320         .008
    263.020        .800     87.709         .004
    218.405        .800    103.556         .006
    278.011        .800     92.575         .005
    149.391        .600     74.030         .006
    160.325        .600     94.330         .004
    307.502        .600    132.536         .004
    372.755        .600    146.350         .003
    237.656        .600    137.331         .009
    229.397        .400    121.553         .003
    473.541        .400    144.558         .004
    392.723        .400    160.539         .003
    498.728        .400    235.617         .002
PEARSON CORR      TARGET GCRS GSPED WITH TARGET GCRS GSPED
OPTIONS           3
STATISTICS        ALL
FINISH
```

Figure 16. Listing of Output Written to File NOTPT for the Regression and Correlation Analyses.

```
SAINT-SPSS EXAMPLE 3                                                                       07/02/76.     PAGE    3

FILE    NONAME    (CREATION DATE =  07/02/76.)

* * * * * * * * * * * * * * * * * * * * * * * *  M U L T I P L E    R E G R E S S I O N  * * * * * * * * * * * * * * * * * * * * * * * *

DEPENDENT VARIABLE..     TARGET

MEAN RESPONSE        284.93887       STD. DEV.      103.83422

VARIABLE(S) ENTERED ON STEP NUMBER    1..    PPATCH

MULTIPLE R              .56156          ANALYSIS OF VARIANCE      DF       SUM OF SQUARES        MEAN SQUARE              F      SIGNIFICANCE
R SQUARE                .31535          REGRESSION                1.         50998.53720        50998.53720          6.44826             .024
STD DEVIATION         88.93197          RESIDUAL                 14.        110724.53695         7908.89550

COEFFICIENT OF VARIABILITY      31.211 PERCENT


-------------------- VARIABLES IN THE EQUATION ----------------------            ---------- VARIABLES NOT IN THE EQUATION -----------

VARIABLE             B          STD ERROR B          F            BETA            VARIABLE      PARTIAL     TOLERANCE          F
                                               ------------   -----------                                                 ------------
                                               SIGNIFICANCE   ELASTICITY                                                  SIGNIFICANCE

PPATCH        -252.48425       93.428966       6.4482629     -.5615561
                                                    .024       -.62027
(CONSTANT)     461.67785       73.065070      39.926245
                                                    .000

ALL VARIABLES ARE IN THE EQUATION.


COEFFICIENTS AND CONFIDENCE INTERVALS.

VARIABLE             B        STD ERROR B           T              95.0 PCT CONFIDENCE INTERVAL

PPATCH        -252.48425      93.428966      -2.5393430          -465.73817    ,  -39.230333
CONSTANT       461.67785      73.065070       6.3187218           304.96887    ,  618.38683

VARIANCE/COVARIANCE MATRIX OF THE UNNORMALIZED REGRESSION COEFFICIENTS.

PPATCH      8728.97337

            PPATCH
```

Figure 17. Results of the SPSS Regression Analysis.

Pearson Correlation Results

The results of the SPSS Pearson correlation analysis are given in Figure 18. These results indicate that there are statistically significant correlations (at the 0.05 level) for the following comparisons:

TARGET vs. GCRS

TARGET vs. GSPED

GCRS vs. GSPED

where:

TARGET = average linear distance

GCRS = average ground course error

GSPED = average ground speed error

The positive correlation (0.79) between TARGET and GCRS suggests that the average ground course error might be used as an effective measure of performance if statistics on TARGET are not available (if GCRS is low then TARGET will also be low).

The GSPED-TARGET and GSPED-GCRS correlations are highly negative (-.66, -.74). This suggests that the ground speed error might also be used as an effective measure of performance (if GSPED is high then TARGET will be low). However, since the ground speed error is recomputed after a patch, care should be taken when using this correlation. This would especially be true if RPV times of arrival at the target were included in the model as secondary performance measures.

SAINT-SPSS EXAMPLE 3 07/02/76. PAGE 6

FILE NONAME (CREATION DATE = 07/02/76.)

VARIABLE	CASES	MEAN	STD DEV
TARGET	16	284.5389	103.8342
GCRS	16	117.3531	42.3558
GSPED	16	.0049	.0018

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR	VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
TARGET	TARGET	16	161723.1742	10781.5449	TARGET	GCRS	16	52113.4209	3474.2281
TARGET	GSPED	16	-1.8719	-.1248	GCRS	TARGET	16	52113.4209	3474.2281
GCRS	GCRS	16	26910.1536	1794.0104	GCRS	GSPED	16	-.8634	-.0576
GSPED	TARGET	16	-1.8719	-.1248	GSPED	GCRS	16	-.8634	-.0576
GSPED	GSPED	16	.0000	.0000					

- - - - - - - - - - - - P E A R S O N   C O R R E L A T I O N   C O E F F I C I E N T S - - - - - - - - - - - -

	TARGET	GCRS	GSPED
TARGET	1.0000	.7900	-.6599
	(16)	(16)	(16)
	S= .001	S= .001	S= .005
GCRS	.7900	1.0000	-.7462
	(16)	(16)	(16)
	S= .001	S= .001	S= .001
GSPED	-.6599	-.7462	1.0000
	(16)	(16)	(16)
	S= .005	S= .001	S= .001

A VALUE OF 99.0000 IS PRINTED IF A COEFFICIENT CANNOT BE COMPUTED.

Figure 18. Results of the SPSS Pearson Correlation Analysis.

SECTION VII

CONCLUSION

An RPV/DCF system in which five RPVs fly along a flight path to a target under the control of a single operator DCF has been hypothesized. A SAINT model of this system has been developed and executed. The results of the execution of the SAINT model have been prepared by subroutine ENDIT for input to the SPSS statistical routines. With this input, the SPSS package has been used to perform statistical analyses on the results of the execution of the SAINT model.

This report has described the above process to illustrate the methodology required for the construction of a SAINT-SPSS interface. This methodology could be applied to any other output of a SAINT simulation (e.g., task statistics or state variable statistics) and to any of the other SPSS analysis procedures (e.g., descriptive statistics or factor analysis). Thus, by employing this methodology, the SAINT user has the capability to analyze his simulation results using an external statistical analysis package.

APPENDIX A

SAINT MODEL INPUT

The following pages list the data input used for the execution of the SAINT model of the RPV/DCF system. Between executions for different analyses, only the number of iterations and the values of distribution set parameters varied (as explained in the text).

```
GEN,SPSS,7,1,1976,1,16,1,77777,1.0,Y*
SGE,0,42,0.001,5.0*
POP,1,2,4,0,7,,,2*
OUT,(14)N,N*
DIS,1,NO,2.0,0.0,99999.,0.5*
DIS,2,NO,2.0,0.0,99999.,0.5*
DIS,3,NO,2.0,0.0,99999.,0.5*
DIS,4,NO,2.0,0.0,99999.,0.5*
DIS,5,CO,1.0*
DIS,6,NO,0.0,-99999.,99999.,0.035*
DIS,7,NO,0.0,-99999.,99999.,10.0*
DIS,8,CO,0.*
UBO,1,TARGET*
UBO,2,GR CRSE*
UBO,3,CR SPEED*
UHI,1,TARGET,50,0.,100.*
UHI,2,GR CRSE,50,0.,100.*
UHI,3,GR SPEED,50,0.,100.*
LRE,1,OPERATOR*
TAS,1,START,0,1,SC,10,,,SO,(15)1*
TAS,2,REQ STUS,1,1,DS,1,(16)1*
TAS,3,WT STUS,1,1,SC,0,(16)1*
TAS,4,OFF CRSS,1,1,DS,2,(16)1*
TAS,5,PATCHS,1,1,SC,0,(16)1*
TAS,6,REQ PTCH,1,1,DS,3,(16)1*
TAS,7,WT PTCH,1,1,SC,0,(16)1*
TAS,8,TURNS,1,1,SC,0,(16)1*
TAS,9,PATCH,1,1,DS,4,(16)1*
TAS,10,SEND PCH,1,1,SC,0*
TAS,11,PROC PCH,1,1,SC,0,(9)1.0*
TAS,12,FR UPDTE,1,1,SC,5,,0.5,SO*
TAS,13,FPPE TRN,1,1,SC,0*
TAS,14,VFPP TRN,1,1,SC,0*
TAS,15,STOP,1,1,SC,0,,,SI*
MOD,3,1,A,T*
MOD,7,2,A,T*
MOD,10,3,A,T*
MOD,11,4,A,T*
MOD,12,5,A,T*
MOD,13,6,A,T*
MOD,14,7,A,T*
ATA,1,COM,IA,,1,SC,0,RA,1,1,DS,8,RA,1,2,DS,9*
ATA,2,COM,IA,,1,UF,1*
ATA,4,COM,IA,,2,UF,2*
ATA,5,COM,IA,,2,UF,3*
ATA,8,COM,IA,,2,UF,4*
ATA,9,STA,IA,,2,UF,5*
DET,1,2*
DET,2,3*
DET,3,4*
DET,6,7*
DET,7,8*
DET,9,2,10*
DET,10,11*
DET,12,12*
CFI,4,2,ALV,0.,2,IA,,5,AGV,0.,2,IA*
CFI,5,2,ALV,0.,2,IA,,6,AGV,0.,2,IA*
CFI,8,2,ALV,0.,2,IA,,9,AGV,0.,2,IA*
LSV,1,FP TRN 1,2,FP TRN 2,3,FP TRN 3,4,FP TRN 4,5,FP TRN 5*
LSV, 6,VP TRN 1, 7,VP TRN 2, 8,VP TRN 3, 9,VP TRN 4,10,VP TRN 5*
```

```
LSV,11,TRUE X 1,12,TRUE X 2,13,TRUE X 3,14,TRUE X 4,15,TRUE X 5*
LSV,16,TRUE Y 1,17,TRUE Y 2,18,TRUE Y 3,19,TRUE Y 4,20,TRUE Y 5*
LSV,21,FPPE X 1,22,FPPE X 2,23,FPPE X 3,24,FPPE X 4,25,FPPE X 5*
LSV,26,FPPE Y 1,27,FPPE Y 2,28,FPPE Y 3,29,FPPE Y 4,30,FPPE Y 5*
LSV,31,VFPP X 1,32,VFPP X 2,33,VFPP X 3,34,VFPP X 4,35,VFPP X 5*
LSV,36,VFPP Y 1,37,VFPP Y 2,38,VFPP Y 3,39,VFPP Y 4,40,VFPP Y 5*
LSV,41,TIME,42,STOP*
MON,1,FPPE 1,41,1,,,P,1.0*
MON,2,FPPE 2,41,2,,,P,1.0*
MON,3,FPPE 3,41,3,,,P,1.0*
MON,4,FPPE 4,41,4,,,P,1.0*
MON,5,FPPE 5,41,5,,,P,1.0*
MON,6,VFPPE 1,41,6,,,P,1.0*
MON,7,VFPPE 2,41,7,,,P,1.0*
MON,8,VFPPE 3,41,8,,,P,1.0*
MON,9,VFPPE 4,41,9,,,P,1.0*
MON,10,VFPPE 5,41,10,,,P,1.0*
MON,11,STOP,42,,,2.0,P,1.0*
MTA,1,13*
MTA,2,13*
MTA,3,13*
MTA,4,13*
MTA,5,13*
MTA,6,14*
MTA,7,14*
MTA,8,14*
MTA,9,14*
MTA,10,14*
MTA,11,15*
MSW,1,1,1*
MSW,2,1,2*
MSW,3,1,3*
MSW,4,1,4*
MSW,5,1,5*
MSW,6,2,1*
MSW,7,2,2*
MSW,8,2,3*
MSW,9,2,4*
MSW,10,2,5*
FIN*
    5
 48. 28. 15. 12. 10.
 60. 40. 14. 11. 10.
    5
 48. 28. 15. 12. 10.
 60. 40. 14. 11. 10.
    5
 48. 28. 15. 12. 10.
 60. 40. 14. 11. 10.
    5
 48. 28. 15. 12. 10.
 60. 40. 14. 11. 10.
    5
 48. 28. 15. 12. 10.
 60. 40. 14. 11. 10.
    5
 48. 28. 15. 12. 10.
 60. 40. 14. 11. 10.
    5
 48. 28. 15. 12. 10.
 60. 40. 14. 11. 10.
```

```
 5
48. 28. 15. 12. 10.
60. 40. 14. 11. 10.
 5
48. 28. 15. 12. 10.
60. 40. 14. 11. 10.
 5
48. 28. 15. 12. 10.
60. 40. 14. 11. 10.
 5
48. 28. 15. 12. 10.
60. 40. 14. 11. 10.
 5
48. 28. 15. 12. 10.
60. 40. 14. 11. 10.
 5
48. 28. 15. 12. 10.
60. 40. 14. 11. 10.
 5
48. 28. 15. 12. 10.
60. 40. 14. 11. 10.
 5
48. 28. 15. 12. 10.
60. 40. 14. 11. 10.
 5
48. 28. 15. 12. 10.
60. 40. 14. 11. 10.
```

APPENDIX B

SAINT DATA ECHO CHECK

The following pages present the echo check of the SAINT model input listed in Appendix A.

SAINT SIMULATION PROJECT 1 BY SPSC
DATE 7/ 1/ 1976

RUN PARAMETERS

PARAMETER	VALUE
NUMBER OF ITERATIONS	16
NUMBER OF SINK TASKS TO END ITERATION	1
INTEGER RANDOM NUMBER SEED	77777
SCALE FACTOR FOR FUNCTION SC	1.000

PROGRAM OPTIONS

OPTION	CODE
NUMBER OF RESOURCES	1
NUMBER OF RESOURCE ATTRIBUTES PER RESOURCE	2
NUMBER OF INFORMATION ATTRIBUTES	4
NUMBER OF SYSTEM ATTRIBUTES	0
NUMBER OF MODERATOR FUNCTIONS	7
NETWORK MODIFICATION	
DISTRIBUTION SET MODIFICATION	
RANKING OF TASKS AWAITING SCHEDULING	2

OUTPUT OPTIONS

OPTION	CODE
DETAILED ITERATION OUTPUT (BEGIN)	0
DETAILED ITERATION OUTPUT (END)	0
RESOURCE UTILIZATION SUMMARY (BEGIN)	0
RESOURCE UTILIZATION SUMMARY (END)	0
STATISTICS TASK SUMMARY (BEGIN)	0
STATISTICS TASK SUMMARY (END)	0
INITIAL/FINAL STATE VARIABLE VALUES (BEGIN)	0
INITIAL/FINAL STATE VARIABLE VALUES (END)	0
STATE VARIABLE STATISTICS (BEGIN)	0
STATE VARIABLE STATISTICS (END)	0
STATE VARIABLE PLOTS/TABLES (BEGIN)	0
STATE VARIABLE PLOTS/TABLES (END)	0
RESOURCE UTILIZATION SUMMARY REPORT	NO
STATISTICS TASK SUMMARY REPORT	NO
HISTOGRAM OUTPUT FOR STATISTICS TASKS	
SUMMARY FOR ITERATION 1	NO
SUMMARY REPORT	NO

USER-GENERATED STATISTICS FOR VARIABLES BASED ON OBSERVATION

VARIABLE NUMBER	VARIABLE LABEL
1	TARGET
2	GR CRSE
3	GR SPEED

USER-GENERATED HISTOGRAMS

VARIABLE NUMBER	VARIABLE LABEL	NUMBER OF CELLS	UPPER LIMIT OF FIRST CELL	CELL WIDTH
1	TARGET	50	0	.1000E+03
2	GR CRSE	50	0	.1000E+03
3	GR SPEED	50	0	.1000E+03

INITIAL MODERATOR FUNCTION STATUS

MODERATOR FUNCTION	INITIAL STATUS
1	INAC
2	INAC
3	INAC
4	INAC
5	INAC
6	INAC
7	INAC

DISTRIBUTION SETS

SET NUMBER	DISTRIBUTION TYPE	PARAMETERS 1	PARAMETERS 2	PARAMETERS 3	PARAMETERS 4
1	NO	2.0000	0	99999.0000	.5000
2	NO	2.0000	0	99999.0000	.5000
3	NO	2.0000	0	99999.0000	.5000
4	NO	2.0000	0	99999.0000	.5000
5	CO	1.0000	0	0	0
6	NO	0	-99999.0000	99999.0000	.0350
7	NO	0	-99999.0000	99[illegible].0000	10.0000
8	CO	0	0	0	0

RESOURCE DESCRIPTIONS

RESOURCE NUMBER	RESOURCE LABEL	ATTRIBUTE NUMBER	ATTRIBUTE VALUE
1	OPERATOR	1	0
		2	0

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TASK DEFINITIONS

TASK NUMBER	TASK LABEL	SPEC CHAR	PREDECESSOR FIRST	PREDECESSOR SUBS	REQTS DIFF	PERFORMANCE FUNC	PERFORMANCE PMTR	TIME RESR	TASK PRTY	INFO CODE	CHOICE ATRIB	COMP PREC	RESR CODE	RESOURCES ASSOCIATED WITH THIS TASK
1	START	SOU	0	1		SC	10		0	LAS		0	AND	1
2	REQ STUS		1	1		DS	1		0	LAS		0	AND	1
3	WT STUS		1	1		SC	0		0	LAS		0	AND	1
4	OFF CRSS		1	1		DS	2		0	LAS		0	AND	1
5	PATCHS		1	1		SC	0		0	LAS		0	AND	1
6	REQ PTCH		1	1		DS	3		0	LAS		0	AND	1
7	WT PTCH		1	1		SC	0		0	LAS		0	AND	1
8	TURNS		1	1		SC	0		0	LAS		0	AND	1
9	PATCH		1	1		DS	4		0	LAS		0	AND	1
10	SEND PCH		1	1		SC	0		0	LAS		0	AND	
11	PROC PCH		1	1		SC	0		1.00	LAS		0	AND	
12	FR UPDTE	SOU	1	1		SC	5		.50	LAS		0	AND	
13	FPPE TRN		1	1		SC	0		0	LAS		0	AND	
14	VFPP TRN		1	1		SC	0		0	LAS		0	AND	
15	STOP	SIN	1	1		SC	0		0	LAS		0	AND	

MODERATOR FUNCTION STATUS UPDATES

TASK NUMBER	UPDATE FUNCTION	UPDATE STATUS	UPDATE DURATION
3	1	ACT	TASK
7	2	ACT	TASK
10	3	ACT	TASK
11	4	ACT	TASK
12	5	ACT	TASK
13	6	ACT	TASK
14	7	ACT	TASK

ATTRIBUTE ASSIGNMENT INFORMATION

TASK NUMBER	ASSIGNMENT POINT	ASSIGNMENT TYPE	RESR NUMBER	ATRIB NUMBER	FUNCTION TYPE	PARAMETER SPEC
1	COM	IA		1	SC	0
		RA	1	1	DS	8
		RA	1	2	DS	5
2	COM	IA		1	UF	1
4	COM	IA		2	UF	2
5	COM	IA		2	UF	3
6	COM	IA		2	UF	4
9	STA	IA		2	UF	5

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DETERMINISTIC BRANCHING

TASK NUMBER	SUCCESSOR TASKS	
1	2	
2	3	
3	4	
6	7	
7	8	
9	2	10
10	11	
12	12	

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ANALYZING SAINT OUTPUT USING SPSS.(U)
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CONDITIONAL BRANCHING

TASK NUMBER	BRANCH TYPE	SUCC TASK	CONDITION CODE	ATRB/ VALUE	ATRB TYPE	RESR NUMBER	COMPARED ATTRIBUTE
4	FIR	2	ALV	0	I4		2
		5	AGV	0	I4		2
5	FIR	2	ALV	0	I4		2
		6	AGV	0	I4		2
8	FIR	2	ALV	0	I4		2
		9	AGV	0	I4		2

STATE VARIABLE GENERAL INFORMATION

NUMBER OF EQUATIONS WRITTEN IN DD	=	0
NUMBER OF EQUATIONS WRITTEN IN SS	=	42
INTEGRATION ERROR OPTION	=	WARN
ABSOLUTE INTEGRATION ERROR ALLOWED	=	.1000E-04
RELATIVE INTEGRATION ERROR ALLOWED	=	.1000E-04
MINIMUM STEP SIZE	=	.1000E-02
MAXIMUM STEP SIZE	=	.5000E+01
COMMUNICATION INTERVAL	=	.1000E+21

STATE VARIABLE DESCRIPTIONS

STATE VARIABLE NUMBER	STATE VARIABLE LABEL
1	FP TRN 1
2	FP TRN 2
3	FP TRN 3
4	FP TRN 4
5	FP TRN 5
6	VP TRN 1
7	VP TRN 2
8	VP TRN 3
9	VP TRN 4
10	VP TRN 5
11	TRUE X 1
12	TRUE X 2
13	TRUE X 3
14	TRUE X 4
15	TRUE X 5
16	TRUE Y 1
17	TRUE Y 2
18	TRUE Y 3
19	TRUE Y 4
20	TRUE Y 5
21	FPPE X 1
22	FPPE X 2
23	FPPE X 3
24	FPPE X 4
25	FPPE X 5
26	FPPE Y 1
27	FPPE Y 2
28	FPPE Y 3
29	FPPE Y 4
30	FPPE Y 5
31	VFPP X 1
32	VFPP X 2
33	VFPP X 3
34	VFPP X 4
35	VFPP X 5
36	VFPP Y 1
37	VFPP Y 2
38	VFPP Y 3
39	VFPP Y 4
40	VFPP Y 5
41	TIME
42	STOP

STATE VARIABLE MONITORS

THRESHOLD SPECIFICATION

MONITOR NUMBER	MONITOR LABEL	VARIABLE TO BE MONITORED	THRESHOLD FUNCTION: MULTIPLICATIVE CONSTANT	* STATE VARIABLE	+ ADDITIVE CONSTANT	CROSSING DIRECTION	TOLERANCE SPECIFICATION
1	FPPE 1	SS(41)	.1000E+01	SS(1)	0	UP	.1000E+01
2	FPPE 2	SS(41)	.1000E+01	SS(2)	0	UP	.1000E+01
3	FPPE 3	SS(41)	.1000E+01	SS(3)	0	UP	.1000E+01
4	FPPE 4	SS(41)	.1000E+01	SS(4)	0	UP	.1000E+01
5	FPPE 5	SS(41)	.1000E+01	SS(5)	0	UP	.1000E+01
6	VFPPE 1	SS(41)	.1000E+01	SS(6)	0	UP	.1000E+01
7	VFPPE 2	SS(41)	.1000E+01	SS(7)	0	UP	.1000E+01
8	VFPPE 3	SS(41)	.1000E+01	SS(8)	0	UP	.1000E+01
9	VFPPE 4	SS(41)	.1000E+01	SS(9)	0	UP	.1000E+01
10	VFPPE 5	SS(41)	.1000E+01	SS(10)	0	UP	.1000E+01
11	STOP	SS(42)			.2000E+01	UP	.1000E+01

TASK SIGNALING CAUSED BY MONITOR ACTION

MONITOR NUMBER	TASKS TO BE SIGNALED
1	13
2	13
3	13
4	13
5	13
6	14
7	14
8	14
9	14
10	14
11	15

SWITCHING CAUSED BY MONITOR ACTION

MONITOR NUMBER	SWITCH AFFECTED	NEW SWITCH VALUE
1	1	1
2	1	2
3	1	3
4	1	4
5	1	5
6	2	1
7	2	2
8	2	3
9	2	4
10	2	5

APPENDIX C

EXAMPLE OUTPUT

This appendix presents output from one iteration of the SAINT model of the RPV/DCF system described in this report. This output consists of:

1. The user-generated statistics collected for the iteration, and

2. The user-generated histograms created for the iteration.

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USER-GENERATED STATISTICS FOR VARIABLES BASED ON OBSERVATION

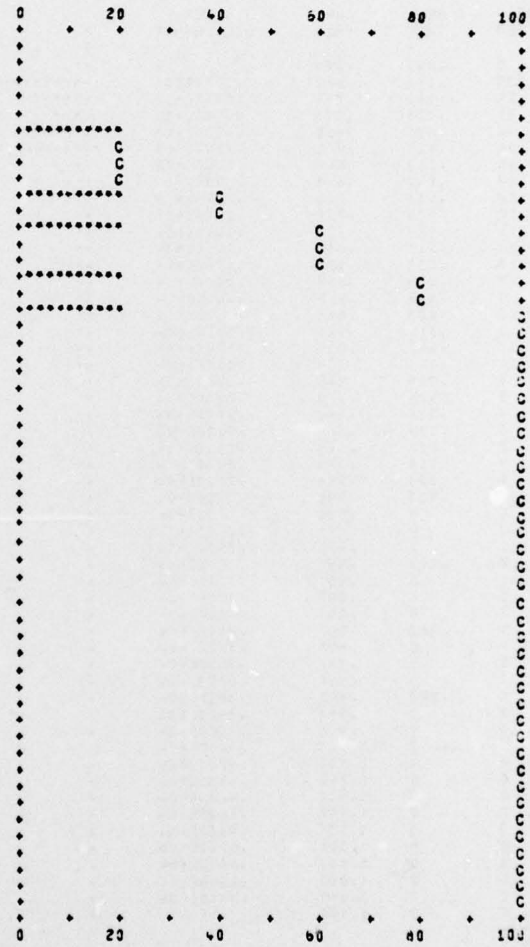
	MEAN	STD DEV	SD OF MEAN	CV	MINIMUM	MAXIMUM	OBS
TARGET	.1047E+04	.4452E+03	.1991E+03	.4251E+00	.4156E+03	.1552E+04	5
GR CRSE	.6329E+03	.6437E+03	.2680E+02	.1017E+01	0	.4089E+04	577
CR SPEED	.3920E+03	.3894E+03	.1621E+02	.9935E+00	0	.2423E+04	577

USER-GENERATED HISTOGRAM NUMBER 1

TARGET

OBSV FREQ	RELA FREQ	CUML FREQ	UPPER CELL LIMIT
0	0	0	0
0	0	0	.1000E+03
0	0	0	.2000E+03
0	0	0	.3000E+03
0	0	0	.4000E+03
1	.200	.200	.5000E+03
0	0	.200	.6000E+03
0	0	.200	.7000E+03
0	0	.200	.8000E+03
1	.200	.400	.9000E+03
0	0	.400	.1000E+04
1	.200	.600	.1100E+04
0	0	.600	.1200E+04
0	0	.600	.1300E+04
1	.200	.800	.1400E+04
0	0	.800	.1500E+04
1	.200	1.000	.1600E+04
0	0	1.000	.1700E+04
0	0	1.000	.1800E+04
0	0	1.000	.1900E+04
0	0	1.000	.2000E+04
0	0	1.000	.2100E+04
0	0	1.000	.2200E+04
0	0	1.000	.2300E+04
0	0	1.000	.2400E+04
0	0	1.000	.2500E+04
0	0	1.000	.2600E+04
0	0	1.000	.2700E+04
0	0	1.000	.2800E+04
0	0	1.000	.2900E+04
0	0	1.000	.3000E+04
0	0	1.000	.3100E+04
0	0	1.000	.3200E+04
0	0	1.000	.3300E+04
0	0	1.000	.3400E+04
0	0	1.000	.3500E+04
0	0	1.000	.3600E+04
0	0	1.000	.3700E+04
0	0	1.000	.3800E+04
0	0	1.000	.3900E+04
0	0	1.000	.4000E+04
0	0	1.000	.4100E+04
0	0	1.000	.4200E+04
0	0	1.000	.4300E+04
0	0	1.000	.4400E+04
0	0	1.000	.4500E+04
0	0	1.000	.4600E+04
0	0	1.000	.4700E+04
0	0	1.000	.4800E+04
0	0	1.000	.4900E+04
0	0	1.000	.5000E+04
0	0	1.000	INF

5			



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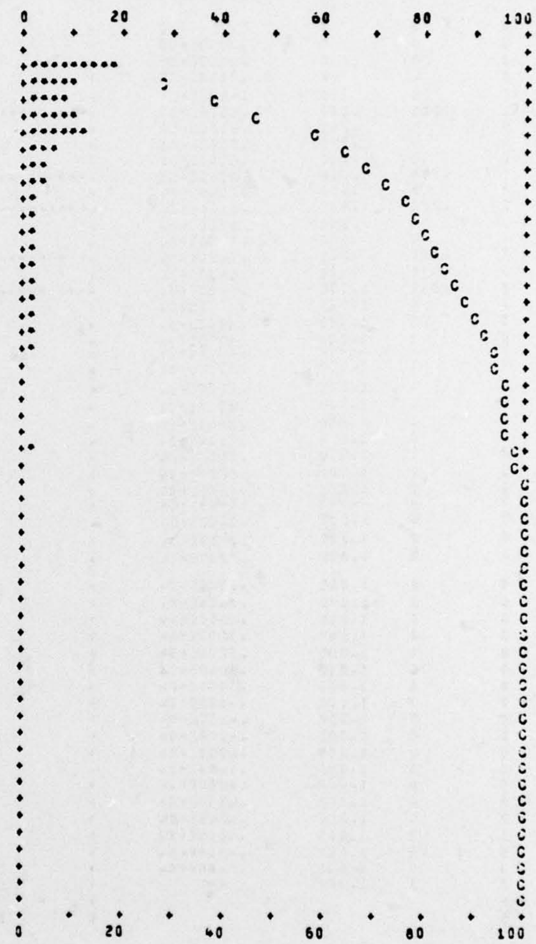
USER-GENERATED HISTOGRAM NUMBER 2

GR CRSE

OBSV FREQ	RELA FREQ	CUML FREQ	UPPER CELL LIMIT
5	.009	.009	0
100	.173	.182	.1000E+03
59	.102	.284	.2000E+03
51	.088	.373	.3000E+03
55	.095	.468	.4000E+03
64	.111	.579	.5000E+03
40	.069	.648	.6000E+03
23	.040	.688	.7000E+03
22	.038	.726	.8000E+03
17	.029	.756	.9000E+03
16	.028	.783	.1000E+04
10	.017	.801	.1100E+04
13	.023	.823	.1200E+04
15	.026	.849	.1300E+04
9	.016	.865	.1400E+04
13	.023	.887	.1500E+04
8	.014	.901	.1600E+04
10	.017	.919	.1700E+04
10	.017	.936	.1800E+04
5	.009	.945	.1900E+04
5	.009	.953	.2000E+04
4	.007	.960	.2100E+04
3	.005	.965	.2200E+04
2	.003	.969	.2300E+04
6	.010	.979	.2400E+04
5	.009	.988	.2500E+04
2	.003	.991	.2600E+04
0	0	.991	.2700E+04
0	0	.991	.2800E+04
0	0	.991	.2900E+04
2	.003	.995	.3000E+04
0	0	.995	.3100E+04
0	0	.995	.3200E+04
0	0	.995	.3300E+04
1	.002	.997	.3400E+04
0	0	.997	.3500E+04
0	0	.997	.3600E+04
0	0	.997	.3700E+04
1	.002	.998	.3800E+04
0	0	.998	.3900E+04
0	0	.998	.4000E+04
1	.002	1.000	.4100E+04
0	0	1.000	.4200E+04
0	0	1.000	.4300E+04
0	0	1.000	.4400E+04
0	0	1.000	.4500E+04
0	0	1.000	.4600E+04
0	0	1.000	.4700E+04
0	0	1.000	.4800E+04
0	0	1.000	.4900E+04
0	0	1.000	.5000E+04
0	0	1.000	INF

577			



USER-GENERATED HISTOGRAM NUMBER 3

GR SPEED

OBSV FREQ	RELA FREQ	CUML FREQ	UPPER CELL LIMIT
5	.009	.009	0
157	.272	.281	.1000E+03
77	.133	.414	.2000E+03
68	.118	.532	.3000E+03
60	.104	.636	.4000E+03
35	.061	.697	.5000E+03
28	.049	.745	.6000E+03
33	.057	.802	.7000E+03
28	.049	.851	.8000E+03
26	.045	.896	.9000E+03
15	.026	.922	.1000E+04
13	.023	.945	.1100E+04
7	.012	.957	.1200E+04
7	.012	.969	.1300E+04
7	.012	.981	.1400E+04
2	.003	.984	.1500E+04
2	.003	.988	.1600E+04
1	.002	.990	.1700E+04
1	.002	.991	.1800E+04
1	.002	.993	.1900E+04
1	.002	.995	.2000E+04
0	0	.995	.2100E+04
1	.002	.997	.2200E+04
1	.002	.998	.2300E+04
0	0	.998	.2400E+04
1	.002	1.000	.2500E+04
0	0	1.000	.2600E+04
0	0	1.000	.2700E+04
0	0	1.000	.2800E+04
0	0	1.000	.2900E+04
0	0	1.000	.3000E+04
0	0	1.000	.3100E+04
0	0	1.000	.3200E+04
0	0	1.000	.3300E+04
0	0	1.000	.3400E+04
0	0	1.000	.3500E+04
0	0	1.000	.3600E+04
0	0	1.000	.3700E+04
0	0	1.000	.3800E+04
0	0	1.000	.3900E+04
0	0	1.000	.4000E+04
0	0	1.000	.4100E+04
0	0	1.000	.4200E+04
0	0	1.000	.4300E+04
0	0	1.000	.4400E+04
0	0	1.000	.4500E+04
0	0	1.000	.4600E+04
0	0	1.000	.4700E+04
0	0	1.000	.4800E+04
0	0	1.000	.4900E+04
0	0	1.000	.5000E+04
0	0	1.000	INF

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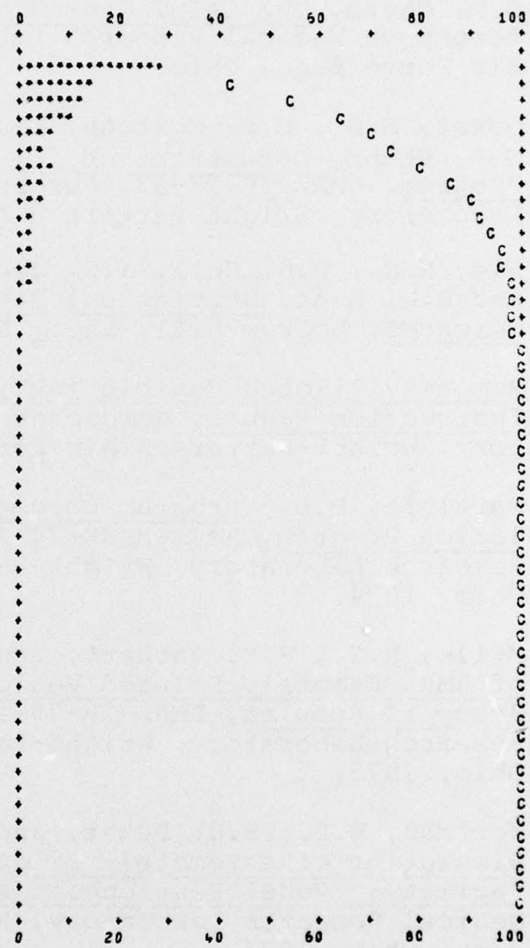

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